LEEDS & NORTHRUP

ELECTRICAL INSTRUMENTS

FOR MEASURING • TESTING • CALIBRATING

CATALOG A 1968/1969

LEEDS & NORTHRUP

ELECTRICAL INSTRUMENTS

FOR MEASURING • TESTING • CALIBRATING

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RANGE OF X OHMS
0.1—1
1—10
10—100
100—1K
1K—10K
10K—100K
100K—1M
1M—10M
10M—100M
100M—1G
1G—10G
MULTIPLY BY
10⁻¹
1
10
10²
10³
10⁴
10⁵
10⁶
10⁷
10⁸
10⁹
10
8
6
4
2
+ ADD
5
6
7
8
4
DETECTOR
SUPPLY
ON

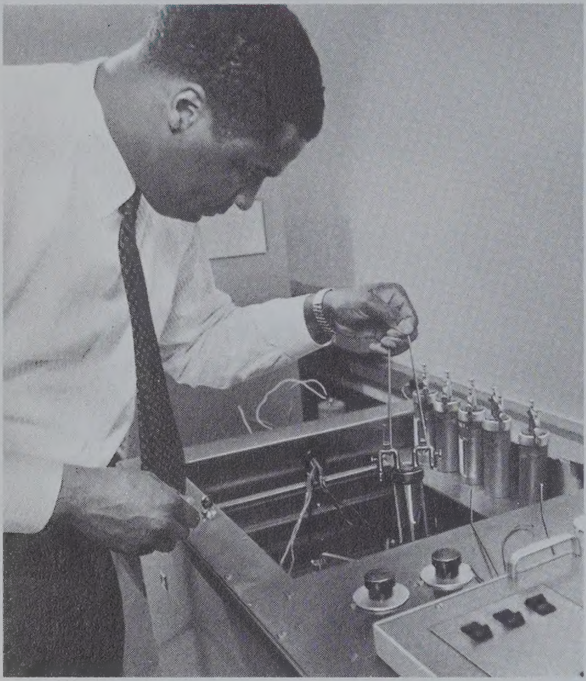
OUR GUARANTEES OF ACCURACY

> “We think it best to allow safe factors and it will be found that almost invariably our adjustments are much better than our guarantees”

from the 1907 Leeds & Northrup catalog, and still quite applicable today

REGISTERED PROFESSIONAL ENGINEER
HENRY E. SOSTMAN
NO. 02801
QUALITY
STATE OF CALIFORNIA

L&N ELECTRICAL MEASURING INSTRUMENTATION



This new, expanded catalog is designed to be a convenient source of purchasing information about the Leeds & Northrup line of electrical measuring instruments for measuring, testing and calibration applications.

Information is provided on bridges, potentiometers and comparators, reference standards for a variety of electrical measurements, and on primary elements, detectors, power supplies, readout devices and laboratory consoles. In addition, descriptions of a variety of custom instruments which were built for specialized customer applications are included to suggest our capabilities in working with you in constructing instrumentation to fit your specific needs.

Each chapter is designed to help you choose the instrument, standard or accessory for your application. Introductory material is provided on the application of instruments and brief descriptions and diagrams review the operation of instruments for various types of measurements. A selection guide based on range, accuracy and application is provided to direct you to the instrument best suited to your use. A summary of ranges and features simplifies the comparison of several instruments. Product descriptions, which include complete specifications, prices and recommended accessories, provide all information required to make a purchasing decision. To further simplify the location of a specific instrument, indexes are provided which list instruments by alphabetical order and by L&N Catalog Number.

A set of file folders, corresponding to the chapters in this catalog, is available for maintaining supplementary information and information on new products.

If you require more specific advice—ranging from the solution of a particular measuring problem to recommendations of suitable L&N instrumentation for a complete laboratory—you'll find us always ready to give your problem individual attention. We invite you to draw on the extensive experience of an L&N field representative for appropriate instrument recommendations. A list of offices will be found on page A-5.

For your convenience, prepaid postcards are provided inside the back cover for requesting a formal quotation or a call by a field representative, for requesting additional literature or for adding your name to our mailing list to receive information on new products.

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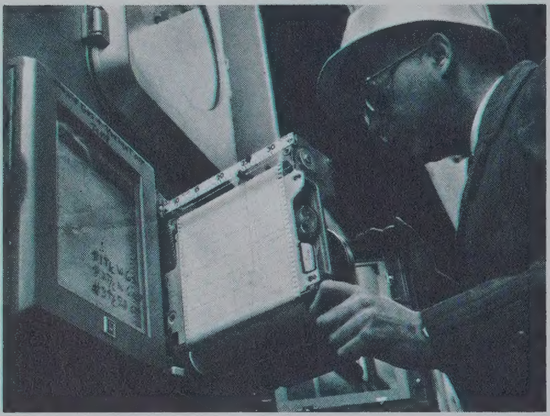
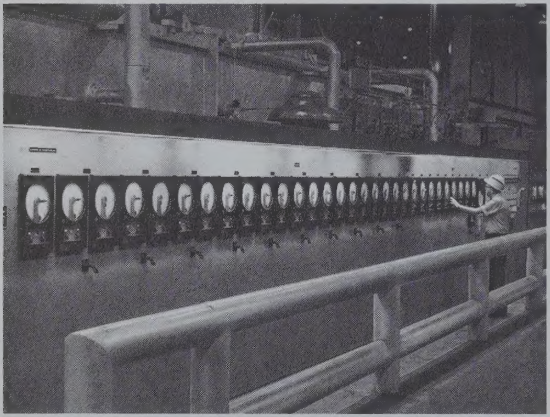
All prices are as of June, 1968 subject to change without notice.

In addition to Electrical Instruments for Measuring, Testing and Calibrating...

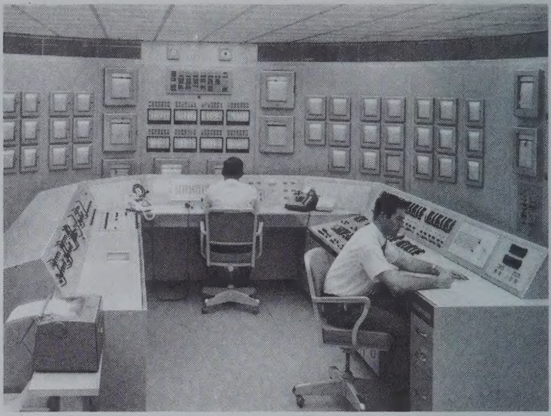
WE MAKE THESE PRODUCTS FOR SCIENCE AND INDUSTRY:



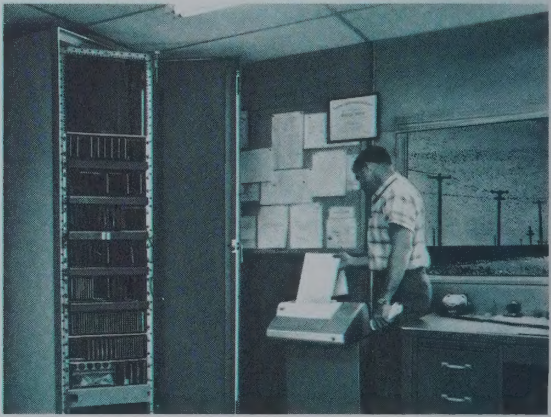
SPEEDOMAX® ELECTRONIC RECORDERS — automatically measure and produce a record of one, two or multiple variables, and are available in a wide selection of models. The compact Speedomax H is supplied as an indicator or as a round- or strip-chart recorder; W provides wide-chart readability in a compact strip-chart recorder; G is used for specialized recording applications; M-Line recorders and indicators are supplied where miniature instrumentation or graphic panels are desired.



AUTOMATIC CONTROLS—operate to keep a measured condition at the desired value. Speedomax instruments are available with a wide variety of control arrangements, including program, auctioneering, cascade and sequence, for two-position or proportioning control. For applications which do not require a chart record, L&N makes Millitemp™ temperature controllers, Precision Set-Point Controllers, and Electromax® Signaling Controllers.

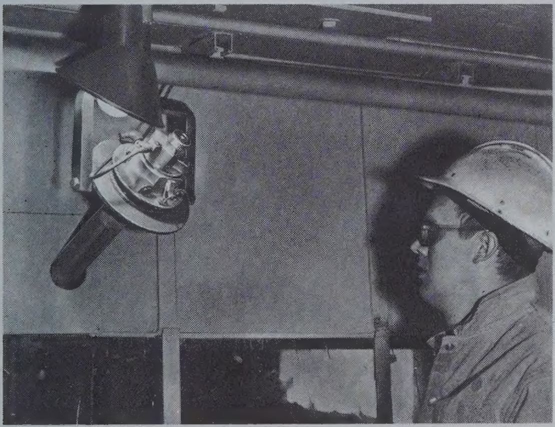


INTEGRATED SYSTEMS—both analog and digital—measure and control all vital variables of complex industrial processes and regulate electric power generation and distribution. These systems—from transducers and transmitters, through panel stations and display devices, to controllers and computer equipment—are designed, engineered, produced and tested by L&N's systems staff.

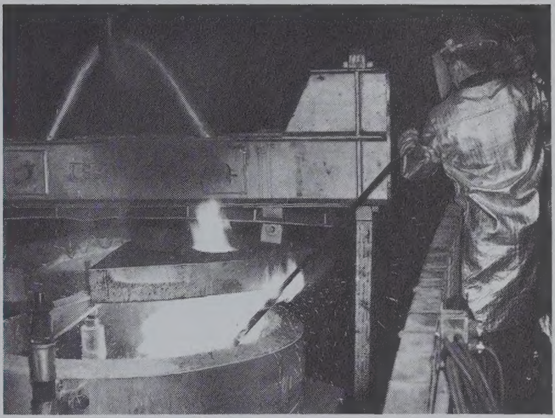


TELEMETERING EQUIPMENT—transmits measurement data from one or more remote points, to a central location where the information is needed. Systems can be either analog, digital, or a combination of the two; can scan for off-normal conditions, actuate alarms, take emergency action. Information can be fed into recording and controlling instruments, punched-tape systems, or computers.

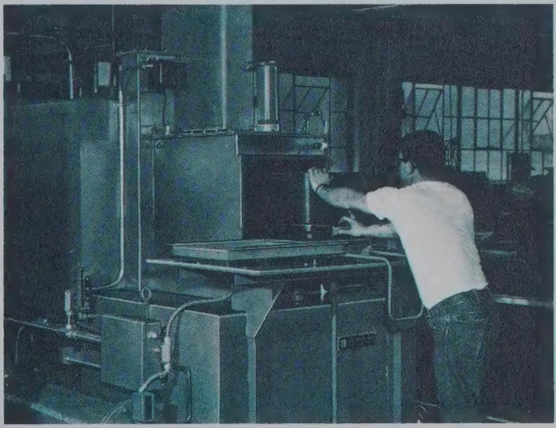
ENVIRONMENTAL & PROCESS INSTRUMENTATION—provides information about the characteristics of liquids or the composition of gases as a guide for laboratory experimental work, for studies of water or air pollution, and for industrial processing. Instrumentation includes analyzers and sampling systems for gas concentration measurements; detection and measuring equipment for determining pH or electrolytic conductivity of liquids.



SENSING ELEMENTS—detect a measurable variable and provide a corresponding electrical signal which is measured by an L&N instrument. Examples include: thermocouples, resistance thermometers, optical or radiation pyrometers for the measurement of temperature, and a variety of sensors for such variables as flow, pressure, weight and position.



EXPENDABLE SENSORS — permit molten - metal measurements to be made during processing. Temtip® expendable thermocouples provide accurate, low - cost temperature measurements. Tectip® thermal-analysis detectors provide low-cost, almost instantaneous analysis (carbon or carbon-equivalent readings) of iron, steel and non-ferrous alloys.



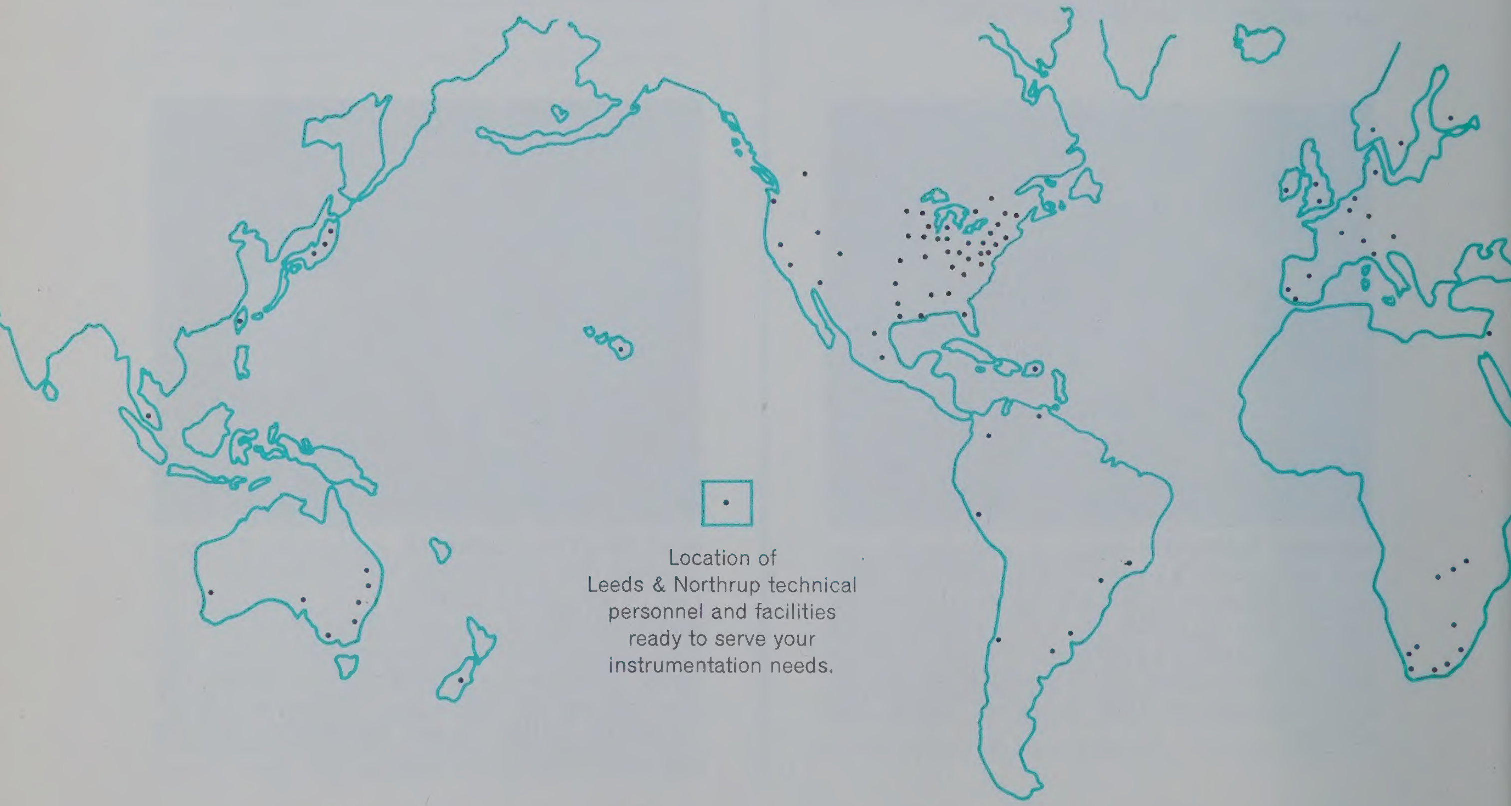
HEAT TREATING FURNACES—comprising the most complete line of batch-type, forced-convection heat treating equipment available today— are used for such heat-treating processes as hardening, normalizing, annealing and tempering, carburizing and carbon restoration, and nitriding. The L&N furnace line includes the well-known Vapocarb®, Homo® Tempering, Steam Homo, Homocarb®, Tricarb® and Homo Nitriding furnaces.

PROMPT ATTENTION TO YOUR REQUIREMENTS...IN THE UNITED STATES...AND THROUGHOUT THE WORLD

In the United States, a large staff of field engineers working out of 49 strategically-located offices is available to provide you with careful recommendations at the time of purchase, to facilitate communication with the factory, to assist in startup, and to handle those many important details related to satisfactory equipment procurement and operation.

These men are graduate engineers who have had extensive factory training (up to 52 weeks). In addition, they have had broad experience in working with scientists, engineers and technicians to evaluate their measurement problems and objectives, and to help them arrive at solutions which are sound, forward-looking, and economically feasible. This is one of your most important guarantees that the proper instrumentation will be selected, and that your requirements will be understood and met.

L&N also has subsidiary companies in Canada, England, Italy, Mexico and Australia, manufacturing licensees in a number of other countries, and representatives in many nations throughout the world.



● Location of Leeds & Northrup technical personnel and facilities ready to serve your instrumentation needs.

LEEDS & NORTHRUP COMPANY

HEADQUARTERS

North Wales, Pa. 19454, U. S. A.

FIELD OFFICES

ALA. 35223, Birmingham, 4 Office Park Circle, Suite 109	205 871-4639
ARIZ. 85019, Phoenix, 3839 N. 39th Ave.	602 272-2540
CAL., L.A.: 1190 Monterey Pass Rd., Monterey Pk., Cal. 91754	213 269-3191
CAL. 94402 San Mateo, 1700 S. El Camino Real	415 349-6656
COLO. 80210, Denver, 2442 South Downing St.	303 744-1047
CONN. 06117, West Hartford, 2535 Albany Ave.	203 232-4474
DEL. 19803, Wilmington, 2625 Concord Pike	302 478-3248
D.C., Washington: 8485 Fenton St., Silver Spring, Md. 20910	301 588-8144
FLA. 32806, Orlando, 14 West Gore St.	305 422-0810
GA. 30305, Atlanta, 2964 Peachtree Rd., N.W.	404 237-8624
ILL., Chicago: 101 S. Washington St., Park Ridge, Ill. 60068	312 825-4402
ILL. 60438, Lansing, 18525 Torrence Ave.	312 474-7070
IND. 46205, Indianapolis, 2511 E. 46th St., Suite R-5	317 545-4364
IOWA, Davenport: 321 8th St., Bettendorf, Iowa 52722	319 355-6439
LA. 70815, Baton Rouge, Post Office Box 15315	504 921-5487
MD., Baltimore: 8485 Fenton St., Silver Spring, Md. 20910	301 588-8144
MASS., Boston: 875 Providence Hwy., Dedham, Mass. 02026	617 326-8816
MICH., Detroit: 20820 Greenfield Rd., Oak Park, Mich. 48237	313 398-3035
MICH. 49503, Grand Rapids, 1444 Michigan, N.E.	616 458-3691
MINN. 55435, Minneapolis, 4940 Viking Drive	612 926-6567
MO. 64114, Kansas City, 7935A1 State Line Rd.	816 523-8199
MO., St. Louis: 8000 Bonhomme Ave., Clayton, Mo. 63105	314 726-0853
NEB. 68132, Omaha, 7000 Dodge St.	402 551-0592
N.J. 07017, East Orange, 99 Washington St.	201 678-0420
N.Y., Albany: 800-19 New Loudon Rd., Latham, N.Y. 12110	518 785-1354
N.Y. 14225, Buffalo, 3343 Harlem Rd.	716 836-5900
N.Y. 10017, New York, 201 East 42nd St.	212 687-4133
N.Y. 14619 Rochester, 474 Thurston Rd.	716 235-1700
N.Y. 13206, Syracuse, 3522 James St.	315 437-3305
N.C. 27103, Winston-Salem, 1250 National Drive	919 723-1087
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OHIO 45236, Cincinnati, 8005 Plainfield Rd.	513 791-2274
OHIO 44124, Cleveland, 5010 Mayfield Rd.	216 291-2100
OHIO 43212, Columbus, 1465 Northwest Blvd.	614 486-7146
OHIO 45439, Dayton, 3864 South Kettering Blvd.	513 293-5033
OHIO 43615, Toledo, 4334 W. Central Ave.	419 531-4489
OKLA. 74135, 5515 East Skelly Drive	918 622-4515
OREGON 97221, Portland, 6415 Southwest Canyon Court	503 292-8945
PA. 18103, Allentown, 3620 Hamilton Blvd.	215 434-4417
PA. 17111, Harrisburg, 2810 Paxton St.	717 564-3523
PA., Philadelphia: Fort Washington, Pa. 19034	215 646-5500
PA. 15234, Pittsburgh, 300 Mt. Lebanon Blvd.	412 561-7808
TENN. 37919, Knoxville, 4711 Old Kingston Pike	615 584-8141
TEXAS 75207, Dallas, 2730 Stemmons Freeway	214 631-1965
TEXAS 77027, Houston, 3939 Essex La.	713 622-8411
UTAH 84111, Salt Lake City, 445 East Second, S.	801 328-8861
VA. 23225, Richmond, 2839 Stratford Hills Shop. Cen.	703 272-1912
WASH. 98109, Seattle, 1311 Republican St.	206 623-5505
W. VA. 25301, Charleston, 1216 Quarrier St.	304 342-6678
WISC. 53226, Milwaukee, 10625 W. North Ave.	414 774-6000

SUBSIDIARIES

AUSTRALIA: Leeds & Northrup Australia Pty. Ltd.,
P. O. Box 155, Alexandria 2015

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41 Constellation Court, Rexdale (Toronto), Ontario

ENGLAND: Leeds & Northrup, Ltd.,
Wharfdale Road, Tyseley, Birmingham 11

ITALY: Leeds & Northrup Italiana S.p.A.,
Casella Postale 3650 Milano I-20100

MEXICO: Leeds & Northrup Mexicana, S.A.,
Apartado Postal 339,
Naucalpan de Juarez

REPRESENTATIVES

ARGENTINA: Coteinar S.R.L.,
Peru 685, Buenos Aires

AUSTRIA: Franz Stadler,
Schottenfeldgasse 14, Wien VII/62

BELGIUM: S. A. Integra,
22, Rue de la Vieille-Montagne, Liege

BRAZIL: Empresa Comercial Importadora, S.A.
Rua Araujo Porto Alegre, 70, 9th Floor,
Suite 903-ZC-P, Rio de Janeiro

CHILE: Carr y Cia S.A.C.,
Casilla 2439, Santiago

COLOMBIA: Automatizacion Ltda.,
Apartado Aeria 4242, Medellin

DENMARK: Semler & Matthiassen,
Aebelogade 1, Copenhagen

FINLAND: Oy. E. Sarlin AB,
P.O. Box 10750, Helsinki 10

FRANCE: S. A. MECI,
123, Bd. de Grenelle, Paris XVe

WEST GERMANY: Deutsche MECI,
Mess-u Regelapparate G.m.b.H,
Munsterstrasse 275, 4 Dusseldorf-Nord

HAWAII: Pell Company, Inc.
P. O. Box 1441, Honolulu 96806

HOLLAND (THE NETHERLANDS): S. A. Integra,
12, Goudsesingel, Rotterdam

ISRAEL: Landseas (Israel) Ltd.,
29 Bezalel Street, P. O. Box 16166, Tel Aviv

JAPAN: Nippon Kikai Keiso Kaisha, Ltd.,
Minamizuka Bldg. No 17-3
Shibuya 2-Chome, Shibuya-ku, Tokyo

NEW ZEALAND: E. C. Gough Ltd.,
P. O. Box 873, Christchurch C1

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PERU: Deltron S. A.
Apartado Postale 1574 Lima

PUERTO RICO: Mario R. Franceschini
P. O. Box 9393, Santurce, 00908

REPUBLIC OF SOUTH AFRICA: Drury Wickman Ltd.,
P. O. Box 3929, Johannesburg

SPAIN: MECI Hispania S.A.,
Padilla 35, Madrid 6

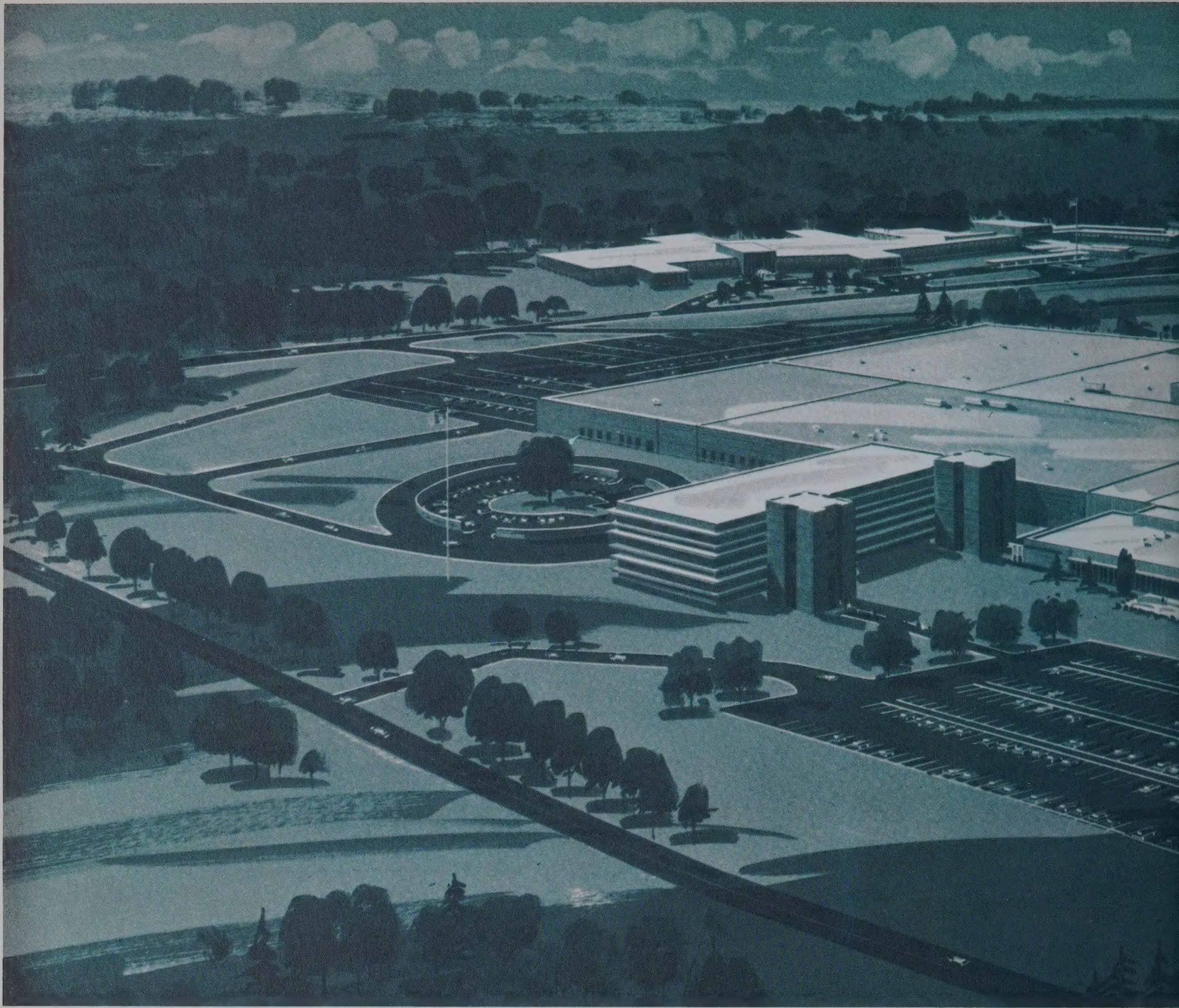
SWEDEN: Aktiebolaget Max Sievert,
Sorterargatan 14, Stockholm-Vallingby

SWITZERLAND: Werner Ness,
Zurichstrasse 129, 8700 Kusnacht-Zurich

TAIWAN: Wah Chang International Corp.,
100 Church Street, New York, N. Y. 10007

URUGUAY: Benech, Industrial y Commercial, S.A.,
J. C. Gomez 1550, Montevideo

VENEZUELA: Ingenieria Electrica C.A.,
M-1 Chacao, Caracas



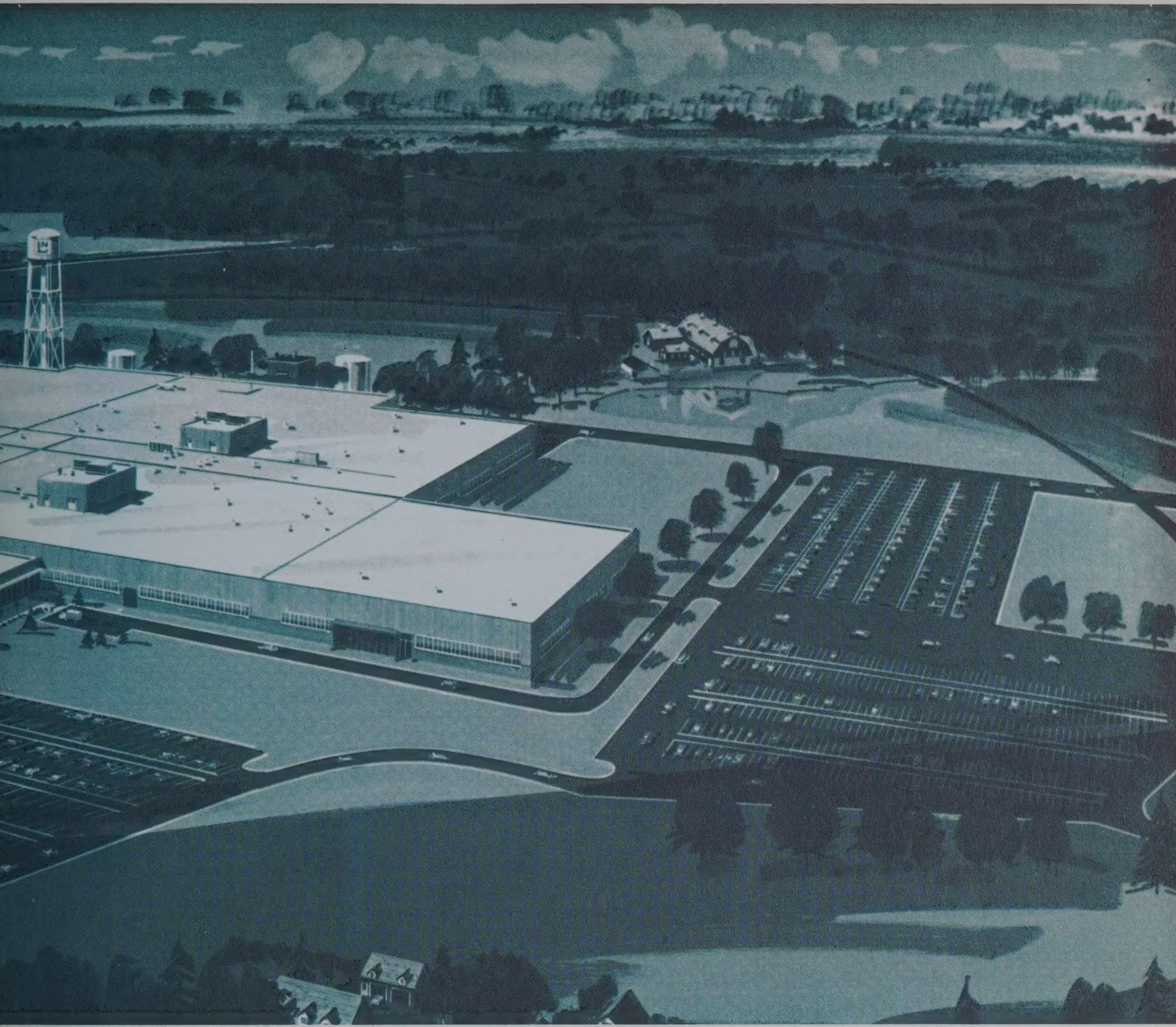
Leeds & Northrup's 130-acre complex at North Wales, Pa., encompasses an Administration Building, an award-winning manufacturing plant, and a

IT'S EASY TO DO BUSINESS WITH LEEDS & NORTHRUP

HOW TO ORDER—To order any of the L&N instruments and accessories described in this catalog, simply specify the List Numbers of the desired items. Be sure to fill in the appropriate suffix number to specify desired range or other options when the List Number includes a -☐. Please send order to your local L&N Field Office. (See listing on page A-5.)

PRICES—All prices listed in this publication are as of June, 1968 and are subject to change without notice. Formal quotations, made on request, are always good for thirty days. Prices are net, f.o.b. factory, North Wales, Pa. Terms are net 30 days. (Discounts on quantity purchases are available; information on request.)

WARRANTY—We warrant to you that the equipment furnished will be free from defects in material and work-



nical Center. Additional U.S. manufacturing facilities are in Philadelphia.

manship, and will be of the kind and quality designated. Should it appear within eighteen months from the date of shipment, or twelve months from the date of installation, whichever period is shorter, that this equipment does not meet the warranty specified above, and you notify us of this promptly, we shall correct any defect, including nonconformance with the specifications, either (at our option) by repairing any defective part or parts which are returned to us freight prepaid, or by making available at your plant (via lowest freight rate) a repaired or replacement part. The conditions of any tests of any of this equipment alleged to be defective shall be mutually agreed upon, and we shall be notified of and may be represented at all tests that may be made. Our liability to you arising out of the supplying of this equipment, or its use, whether on warranty, contract, or negligence, shall not in any case exceed the cost of correcting defects in the equipment provided, and upon the expiration of the warranty period, all such liability shall terminate. In no event shall we be liable for special or consequential damages, and we disclaim all responsibility of every kind should this equipment be used in or with any nuclear installation or activity.

FEDERAL STOCK NUMBERS—For the convenience of those procuring equipment for government installations, Federal Stock Numbers for frequently-purchased items of L&N instrumentation are listed on page L-8.

FOR YOUR CONVENIENCE—Prepaid postcards are provided inside the back cover of this catalog for your convenience in requesting a field representative to call, a formal quotation, or more information from L&N.

A LONG-STANDING DEDICATION TO ADVANCING THE "STATE-OF-THE-ART"

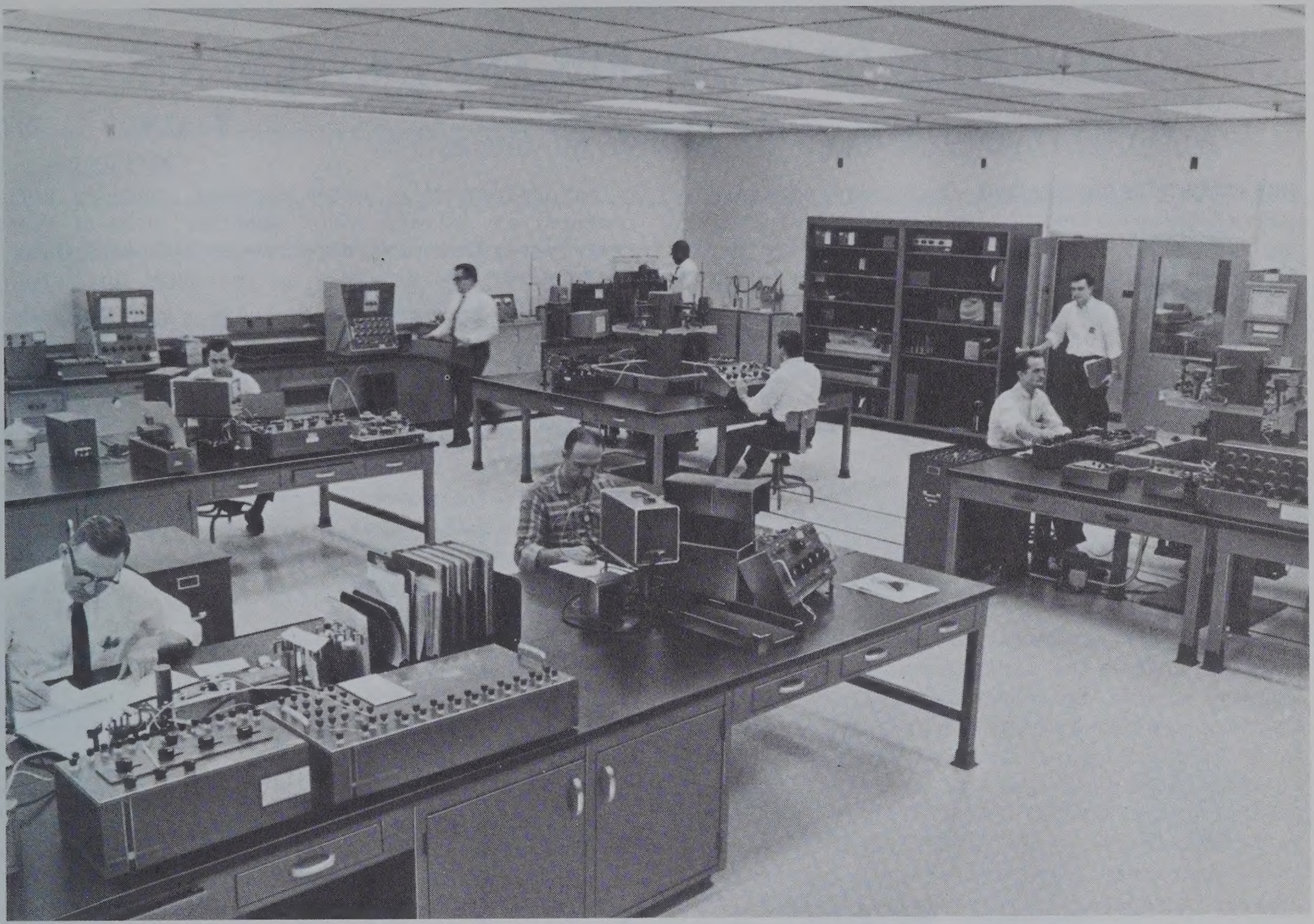
"I am making a plea for a conception and organization of research which will allow it to emerge as a distinct department in any growing technical business and take its proper place just as sales, production, and accounting do."

This quotation from an article by Morris E. Leeds in the November 14, 1919 issue of *Science* is indicative of the long-standing awareness of the importance of R&D at Leeds & Northrup. It was in the year 1911 that Leeds first established an "Experimental Department"—an idea far in advance of its time.

The many contributions which L&N has made in the field of instrumentation—some of the outstanding ones well before there was any market demand for them—are a reflection of this foresight.

Today, L&N researchers continue to advance the state-of-the-art utilizing the extensive facilities in our recently-completed Technical Center in North Wales.

The Laboratory Equipment Division conceives and evaluates new circuits, components and materials, develops working models or prototypes of new instruments, and designs production instruments which meet the exacting requirements for which they have been developed. In addition, Laboratory Equipment Division engineers can work closely with you to modify standard instruments for your specific applications, or to engineer custom instruments to meet your specifications.



ULTRA-MODERN STANDARDS LABORATORY PROVIDES TRACEABILITY BACKUP

Leeds & Northrup has had a formal standards laboratory for over 50 years. When the lab was recently relocated to the present quarters in our North Wales facility, the opportunity was presented to literally build the new lab from bedrock. The resulting laboratory is 5400 sq ft in area, of which 1600 sq ft comprises a primary area with carefully-controlled ambience for the most demanding work.

This primary area is held at 25 C and rarely varies from this figure by more than 0.05 C. Relative humidity is held under 50% and is usually between 30 and 40%. A multi-point Speedomax recorder, with twelve resistance thermometer detectors, monitors the temperature at strategic points throughout the room. Cleanliness is maintained at "grey-room" levels through positive air pressure in the room, air filters, an air-lock entrance, precleaning of instruments and shoe-cleaning devices.

The floor of the primary lab is heavier than that in the remainder of the building and is isolated to eliminate vibration. Galvanometer piers are mounted on heavy concrete blocks, supported from bedrock.

The permanent work stations include:

Primary Resistance-Standard Facility
Standard-Cell Calibration Facility
Potentiometer Checking Station
General-Purpose Resistance Facility
Special Resistance-Standard Facility
Resistance-Thermometer Calibration Facility
General-Purpose Temperature-Controlled Bath
Galvanometer Piers
Ratio-Set Calibration Unit
Type K Potentiometer Test Stand

This primary standards laboratory is responsible for maintaining the accuracy of measurements to the degree of precision required for all L&N products, and for assuring traceability to the National Bureau of Standards. Specific functions include responsibility for the maintenance, on a regular recall basis, of over 700 resistance standards and 1200 instruments used in our own manufacturing operations and for providing equipment for calibration of new L&N instruments.

CALIBRATION OF STANDARDS AND INSTRUMENTS

NBS REPORTS OF CALIBRATION—Occasionally you may require calibration of precision-type standards and measuring instruments purchased from L&N. When these calibration needs have special aspects requiring that the work be done by the National Bureau of Standards, and the equipment is a basic standard, the Bureau will accept a request for calibration. L&N supplies an NBS Report of Calibration with the 4210 Thomas One-Ohm Standard (charge included in price) and will, on request, procure an NBS Report of Calibration (at additional charge) for 8700, 8710 and Std 780-B platinum thermocouples. For all other equipment, you should negotiate directly with the Bureau to arrange for calibration.

L&N REPORTS OF CALIBRATION—As a service to our customers, we can provide an L&N Report of Calibration for some of our primary standards, bridges and potentiometers (as noted in the particular specifications on the following pages). The calibration values are based on standards maintained by L&N and calibrated periodically by the National Bureau of Standards, thus assuring direct "traceability" to the Bureau. L&N Reports of Calibration, giving all correction data usually considered necessary by the Bureau, are in some cases included in the price of the instrument; where available but not included, they can be supplied at nominal additional charge. The availability of each report, with its price, is noted in this catalog with the appropriate instrument. Reports are specified by adding suffix "-B" to the List Number.

A series of Calibration Reports on a given instrument over a period of time provides a history of performance and establishes a pattern of stability. The performance of our certification facilities has been recognized as one of the best in the country, resulting in valid reports which continue to qualify instruments for use beyond expiration of the original guarantee period.

For instruments of lesser accuracy, checking procedures are followed which duplicate those of new instruments. Statements of Conformance re-qualify these instruments after expiration of the initial guarantee.

RECALIBRATION—As an added service to our customers, L&N can provide periodic recalibration for instruments of our manufacture. These reports provide correction data, conditions of test, and traceability information, and are available for:

Capacitance Standards
Current Transformer Test Sets
Inductance Standards
Kelvin and Wheatstone Bridges
Macbeth Illuminometer
Mueller Bridges
Null-Balance Potentiometers (portable & precision)
Optical Pyrometers
Platinum Resistance Thermometers
Platinum Thermocouples
Ratio Sets
Resistance Boxes
Resistance Standards
Shunts
Standard Cells
Temperature Bridges
Volt Boxes
Voltage Dividers

Established fees for this service cover: a general-condition "trouble-shooting" check of your instrument; an overall cleaning, including exposed contacts, slidewires, terminals, etc.; amalgamating of terminals when necessary; and the preparation of a Report of Calibration furnishing precise calibration data. More extensive repairs will be made only at your request and are not included in the established recalibration prices.

TRACEABILITY TO NBS

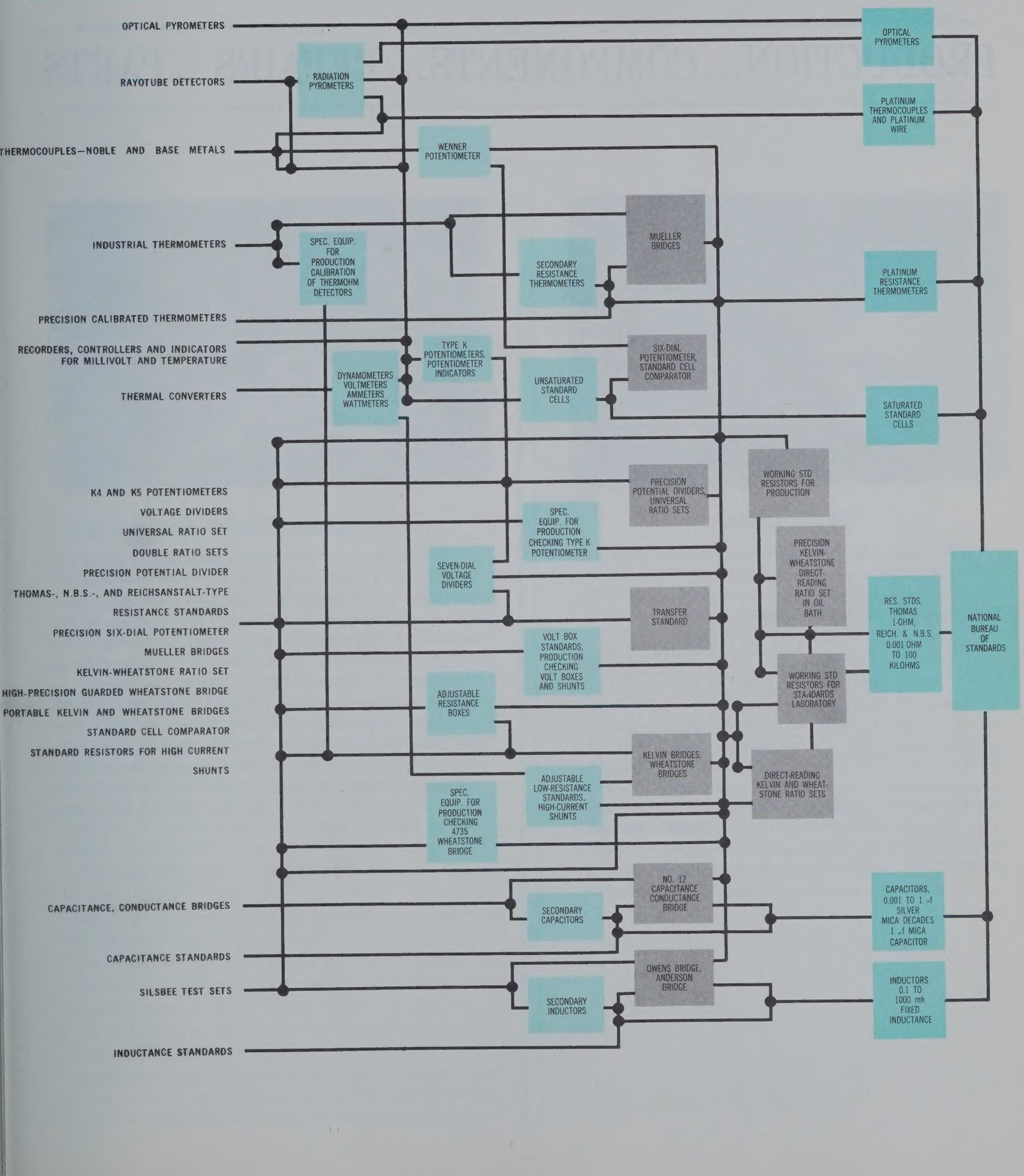
The chart on the facing page shows the traceability of L&N measurements to the National Bureau of Standards. At the right side of this chart are the primary reference standards which are sent to the NBS for certification at regular intervals. These include optical pyrometers, platinum, 10% rhodium-platinum thermocouples, and platinum resistance thermometers. Temperature measurements over the range of −183 C to 2800 C are referenced to these standards. Twelve saturated standard cells comprise our voltage reference standard.

Seventeen primary standards of resistance having values from 0.001 ohm to 100,000 ohms are used to calibrate approximately 500 Reichsanstalt, NBS and Thomas-type working resistance standards.

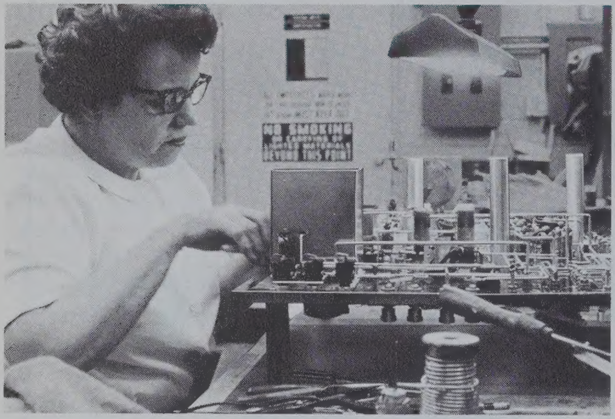
Two silvered-mica decade capacitors with a range of 0.001 μF to 1 μF and a fixed 1-μF mica capacitor serve as reference standards for capacitance measurements. Inductance measurements are referenced to nine fixed inductance standards having nominal values of 0.1 to 1000 mH.

TYPICAL COMPANY PRODUCTS

CALIBRATION INSTRUMENTATION AND REFERENCE STANDARDS


OPTICAL PYROMETERS
RAYOTUBE DETECTORS
THERMOCOUPLES—NOBLE AND BASE METALS
INDUSTRIAL THERMOMETERS
PRECISION CALIBRATED THERMOMETERS
RECORDERS, CONTROLLERS AND INDICATORS FOR MILLIVOLT AND TEMPERATURE
THERMAL CONVERTERS
K4 AND K5 POTENTIOMETERS
VOLTAGE DIVIDERS
UNIVERSAL RATIO SET
DOUBLE RATIO SETS
PRECISION POTENTIAL DIVIDER
THOMAS-, N.B.S.-, AND REICHSANSTALT-TYPE RESISTANCE STANDARDS
PRECISION SIX-DIAL POTENTIOMETER
MUELLER BRIDGES
KELVIN-WHEATSTONE RATIO SET
HIGH-PRECISION GUARDED WHEATSTONE BRIDGE
PORTABLE KELVIN AND WHEATSTONE BRIDGES
STANDARD CELL COMPARATOR
STANDARD RESISTORS FOR HIGH CURRENT SHUNTS
CAPACITANCE, CONDUCTANCE BRIDGES
CAPACITANCE STANDARDS
SILSBEE TEST SETS
INDUCTANCE STANDARDS
RADIATION PYROMETERS
WENNER POTENTIOMETER
SPEC. EQUIP. FOR PRODUCTION CALIBRATION OF THERMOHM DETECTORS
MUELLER BRIDGES
SECONDARY RESISTANCE THERMOMETERS
TYPE K POTENTIOMETERS, POTENTIOMETER INDICATORS
DYNAMOMETERS VOLTMETERS AMMETERS WATTMETERS
SIX-DIAL POTENTIOMETER, STANDARD CELL COMPARATOR
UNSATURATED STANDARD CELLS
PRECISION POTENTIAL DIVIDERS, UNIVERSAL RATIO SETS
WORKING STD RESISTORS FOR PRODUCTION
SPEC. EQUIP. FOR PRODUCTION CHECKING TYPE K POTENTIOMETER
SEVEN-DIAL VOLTAGE DIVIDERS
PRECISION KELVIN-WHEATSTONE DIRECT-READING RATIO SET IN OIL BATH
TRANSFER STANDARD
VOLT BOX STANDARDS, PRODUCTION CHECKING VOLT BOXES AND SHUNTS
WORKING STD RESISTORS FOR STANDARDS LABORATORY
ADJUSTABLE RESISTANCE BOXES
KELVIN BRIDGES, WHEATSTONE BRIDGES
DIRECT-READING KELVIN AND WHEATSTONE RATIO SETS
ADJUSTABLE LOW-RESISTANCE STANDARDS, HIGH-CURRENT SHUNTS
SPEC. EQUIP. FOR PRODUCTION CHECKING 4735 WHEATSTONE BRIDGE
NO. 12 CAPACITANCE CONDUCTANCE BRIDGE
SECONDARY CAPACITORS
OWENS BRIDGE, ANDERSON BRIDGE
SECONDARY INDUCTORS
OPTICAL PYROMETERS
PLATINUM THERMOCOUPLES AND PLATINUM WIRE
PLATINUM RESISTANCE THERMOMETERS
SATURATED STANDARD CELLS
RES. STDS. THOMAS 1-OHM, REICH. & N.B.S. 0.001 OHM TO 100 KILOHMS
NATIONAL BUREAU OF STANDARDS
CAPACITORS, 0.001 TO 1 μf SILVER MICA DECADES 1 μf MICA CAPACITOR
INDUCTORS 0.1 TO 1000 mh FIXED INDUCTANCE

PRODUCTION...COMPONENTS...REPAIRS...PARTS



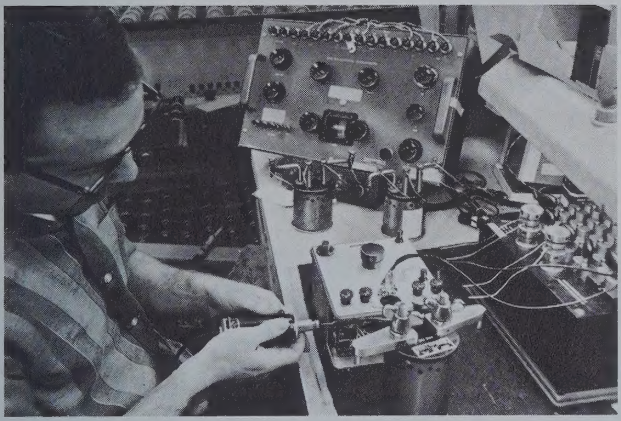
PRODUCTION

Expert craftsmanship and meticulous attention to construction details—from the manufacture of components, through final assembly to final testing—go into the production of every L&N instrument.

Many standard instruments are manufactured by the latest assembly-line techniques, with thorough testing and checking procedures in effect to back up the L&N reputation for quality. Extremely high-precision instruments, as well as custom instruments, are produced in a separate area. Unique arrangements, which were first constructed in this custom production area, have frequently resulted in new standard instruments. The high-precision production area is, in effect, a secondary standards lab, and can be utilized for customer instrument calibration and the maintenance of instruments used in production. In addition, a completely independent quality-control laboratory maintains a constant check on all production areas.

COMPONENTS AND SUB-ASSEMBLIES

Components, such as precision resistors, switches, and binding posts, and sub-assemblies, such as analog integrators, servo-motors, d-c and a-c amplifiers, galvanometer systems, and converters, are carefully manufactured by L&N to assure the necessary performance and mutual compatibility. These components have set new standards in instrumentation, and their construction by L&N permits complete control over the ultimate performance of completed instruments. Modifications and alternative versions can be readily constructed because of manufacture in our own facility. Components are one of the important keys to successful and reliable results and we are not dependent on outside sources for critical components.



REPAIRS

We have extensive repair facilities for restoration of all of our instruments, with short delivery for most work. Equipped with the proper facilities and all necessary repair parts, skilled craftsmen devoted solely to repair will restore your instrument with all possible speed, enabling you to get "as new" performance even from those "veterans" no longer offered for sale. More extensive repairs are accommodated in our production facilities, resulting in instruments which are "as good as new". Repaired instruments must pass inspection in the same manner as a new instrument. The repairs are economical for the work being done, because the same techniques are used for repair as for construction of the original instrument. Repairs are completed with all possible speed; normally within two weeks from receipt.

You may specify any of four types of repair depending on your requirements:

Type 1—Emergency repair to operable condition—not to L&N specifications.

Type 2—Conformance to L&N electrical specifications.

Type 3—Conformance to L&N electrical and mechanical specifications.

Type 4—Complete reconditioning—conformance to L&N electrical, mechanical and physical specifications.

In addition, approximately 90 full-time servicemen are in the field to provide prompt on-the-spot attention should any problem arise with your L&N instrumentation.

INVENTORY

In order to provide for prompt availability of instruments and to permit rapid completion of customer orders, we maintain large stocks of completed instruments, components and sub-assemblies. You can thereby be served with equipment when needed . . . equipment made of resistors and decades that are well-aged and periodically re-checked to insure that they qualify for our guaranteed performance ratings. By means of this large inventory, we can build the instrumentation properly, allowing ample time for the necessary verification of performance yet maintaining short delivery schedules from order date to shipment.

Replacement Parts Policy—L&N will endeavor to make available replacement L&N-produced functional parts for at least ten years following the date of withdrawal from general sale of the cataloged product in which the parts are used.

TECHNICAL INFORMATION, TRAINING COURSES AND SEMINARS

Laboratory Equipment Application Bulletin
Modern Precision
Technical Journal
Moving Coil Galvanometers
Note Book
Fault Locati
in Cab
D-C Bridge Metho
Fundamentals of DC Electrical M

TECHNICAL INFORMATION

To help keep you informed of developments in the field of electrical laboratory instrumentation, Leeds & Northrup publishes an interesting selection of technical information. To receive a copy of any of this material, or to get on the mailing list for any of the periodicals, contact your local L&N sales office or write us directly at North Wales.

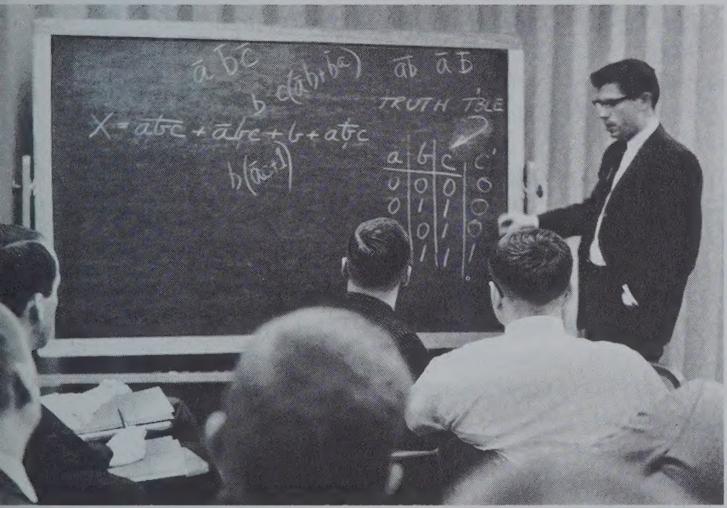
MODERN PRECISION—This highly-informative tabloid is distributed several times a year to over 130,000 technical people in industry, research and education. *Modern Precision* reports on a variety of interesting applications of L&N equipment, and announces new products and new literature.

TECHNICAL JOURNAL—Also published several times a year, this magazine is devoted to technical articles by both Leeds & Northrup personnel and guest authors. The Journal provides in-depth information on subjects of current interest in instrumentation and control.

LABORATORY EQUIPMENT APPLICATION BULLETINS These bulletins provide detailed descriptions and illustrations of interesting applications of L&N equipment.

TECHNICAL LITERATURE—Over the years L&N has published a series of notebooks and technical publications containing basic instrumentation information. In addition, we frequently publish reprints of talks presented by L&N personnel at technical meetings, and reprints of articles published in the instrumentation periodicals which present information about new applications for existing instruments and important new techniques. See page L-8 for a listing of technical literature available from L&N.

CALIBRATION PROCEDURES — These Calibration Procedures permit you to follow best practice in certifying and checking our instruments. Special attention is given to



integrating these procedures with our electrical designs so that the proper connection points are readily available to simplify and authenticate the calibration practice. More efficient calibration is a cost-saving benefit for the lifetime of the instrument.

COMPLETE DIRECTION BOOKS AND PARTS BOOKS—Our Direction Books are extensive, providing the usual information on theory of operation and setup, but, in addition, these manuals include information on technique and specific step-by-step instruction for *each* conventional application. Detailed Parts Books identify each instrument part number on cutaway and exploded photographs for rapid identification of replacement parts.

TRAINING COURSES

The L&N Customer Training Center offers two courses in d-c electrical measurements, to enable you to get the most out of L&N instrumentation. The basic "Fundamentals of D-C Electrical Measurements", a one-week course, is provided at no charge and consists of lectures and laboratory exercises to familiarize the student with potentiometers, Wheatstone bridges, Kelvin bridges, and other basic d-c measuring instruments. The "Precision D-C Measurements and Standards Seminar", also one week in length, is priced at $150.00. This course covers a broad scope of d-c measurements at a high level of precision and accuracy, and presents both the theoretical and actual aspects of measurement. Your Field Engineer can supply you further information and application blanks.

SEMINARS

Through periodic seminars, such as those held in the past at Stanford Research Institute, George Washington University, and at our North Wales plant, we provide a means for exchange of information on measurement techniques and instrumentation development, thereby fostering an awareness of latest measurement practice and user requirements.

THE COMPANY WHICH CONTINUALLY "PIONEERS IN PRECISION"

The Leeds & Northrup Company was founded in 1899 by Morris E. Leeds and incorporated in 1903 under the present name to produce a line of precision electrical measuring instruments for laboratory use.

The company's first significant contribution to modern instrumentation was the "Type K" potentiometer. An instrument for measuring or comparing electromotive forces, it was introduced in 1903 and became one of the most widely used potentiometers in the world.

Ever since those early days we have been privileged to work closely with the National Bureau of Standards and have built many of the instruments designed by Bureau scientists. Indeed, the names of many early Leeds & Northrup instruments reflect their Bureau designers—Dr. Herbert B. Brooks (Potentiometer), Dr. Walter P. White (Potentiometer), Dr. Eugene F. Mueller (Resistance Thermometer Bridge), Dr. Frank Wenner (Potentiometer) and Dr. James L. Thomas (One-Ohm Standard).

We have also worked with privately-operated scientific institutes, educational institutions and industrial research laboratories. These associations not only have led to the solution of many measuring problems, but have significantly advanced the instrumentation art.

The Leeds Recorder, introduced in 1912, was a great pioneering achievement in industrial instrumentation and the first practical recording potentiometer developed specifically for industrial plant applications. It filled industry's need for greater measuring accuracy, as technical processes were developing in speed and complexity.

L&N marketed in 1932 the world's first all-electronic recorder, under the trade name "Speedomax"—leading in turn to the present widely-used Speedomax "G", "H", "M", "W" and "W/L" lines of instruments.

There are now some 2000 products manufactured at L&N, with literally millions of combinations and variations. These include precision electrical measuring instruments; thermocouples and other primary elements; electronic recorders, controllers and control systems; analog and digital computers; process analyzers; and heat treating furnaces.

Over 3000 men and women are employed in our plants in Philadelphia and North Wales, Pennsylvania, and in 49 field sales offices throughout the nation.

Information about our world-wide operations will be found on pages A-4 and A-5.

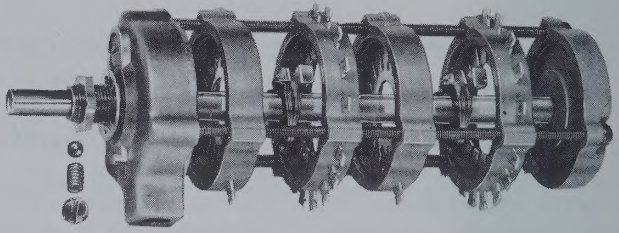
A SELECTION OF LEEDS & NORTHRUP PATENTS RELATING TO PRECISION ELECTRICAL MEASUREMENTS

1902	703,777	Fisher Cable Testing Apparatus
1903	739,001	Hoopes Conductivity Bridge
1905	792,843	Types P and HS Galvanometer
1906	819,355	Type K Potentiometer
1907	862,842	Improved slidewire rheostat
1910	950,513	Use of three thermometer leads to eliminate error
	965,824	First Leeds Recorder patent
1914	1,097,651	Leeds' Wheatstone bridge for temperature measurements
1915	1,132,591	Method for correcting variations in temperature in one junction of thermocouple
1918	1,252,598	Macbeth Illuminometer
1919	1,319,805	Optical Pyrometer
1926	1,587,010	Improved sensitivity with moving-coil galvanometer
1932	1,840,635	Wheatstone bridge for conductance/resistance measurements
1934	1,972,499	Bifilar woven resistor
	1,972,720	Cross-shot woven resistor
1935	2,005,986	Improved resistance box
1936	2,026,616	Fibre wrap for precision resistors
	2,031,050	Method for obtaining current/voltage from commercial source
1940	2,199,810	Improved woven resistor
1941	2,267,551	Electro-Chemograph
1947	2,416,972	Multiple-contact wafer switch
1953	2,659,047	Current-measuring system for polarographic analysis
1954	2,687,510	Improved method for lead-resistance compensation
1965	3,190,993	Switch with mercury-wetted contacts for rapid automatic operation in low-level precision d-c apparatus
1966	3,271,534	Multi-point rotary switch with improved detent arrangement
1967	3,305,803	Low-thermal emf contactor for d-c potentials and nanovolt levels
	3,307,104	Direct-reading Kelvin bridge including compensating slidewires

SPECIAL COMPONENTS AND CONSTRUCTION TECHNIQUES CONTRIBUTE TO THE L&N REPUTATION FOR EXCELLENCE

TYPE 31 SELECTOR SWITCHES

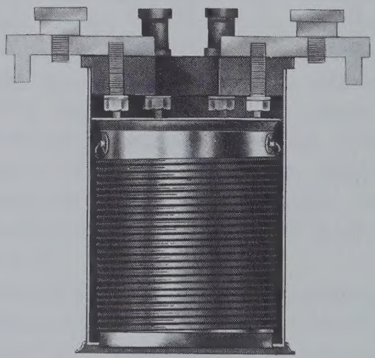
L&N Type 31 silver-silver alloy switches assure low, stable contact resistance (less than 0.001 ohm per contact, reproducible to better than 0.0002 ohm when contacts are paralleled), and negligible thermal emfs (less than 0.1 μV with switch operated at normal speed). Life tests on these switches show negligible change in contact resistance after hundreds of thousands of operations. Totally-enclosed construction eliminates periodic cleaning of brushes and contact studs.



VARIOUS TYPES OF MANGANIN

A variety of types of manganin wire are utilized in the construction of L&N resistors. L&N Grade A manganin (which has a nominal peak of 28 ±5 C) is used for resistance standards. Other types include shunt-grade manganin (45 ±5 C) for minimum ΔR under load, Mueller-bridge grade (33 C), and Thomas-Type One-Ohm Standard grade (25 C).

Resistors are constructed in a variety of configurations, including bifilar spirals, bifilar folded manganin strip, bifilar wound on brass or ceramic spools, and woven resistors mounted on ceramic spools or bakelite cards.

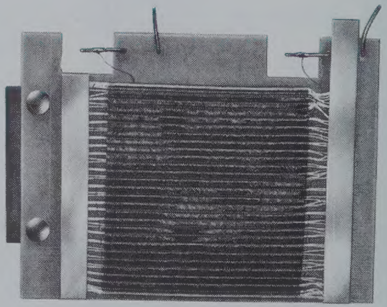


USE OF CONTINUOUS LENGTH OF MANGANIN WIRE

The maintenance of stable ratios with changes in time and temperature is especially important in precision ratio devices such as ratio sets, potentiometers, and volt boxes. By manufacturing all of the critical resistors from consecutive lengths from the same spool of wire, L&N assures matching of these characteristics.

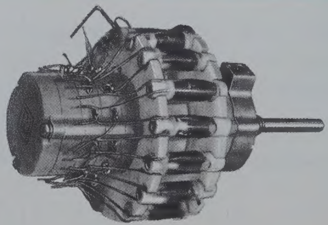
WOVEN RESISTORS

Woven resistors were developed in our Research Department to provide a resistor with the best possible a-c characteristics. The resistance wire is woven into various patterns with silk or Dacron as the warp and selvage, and the resistor is mounted on ceramic spools or phenolic cards. These resistors range in value from about 100 ohms to the megohm region. They are also convenient in d-c circuits where it is desirable to get a high resistance into a relatively small space. Woven resistors have good heat-dissipation characteristics and are usually held on the form by means of warp threads, which makes them practically strain-free.



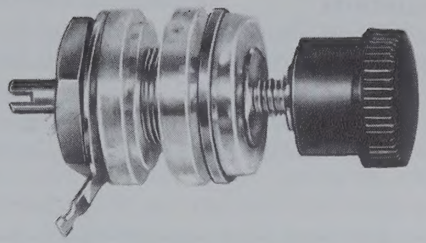
INTEGRAL DECADES

Resistors are mounted directly on the switch body to form an integral decade which is carefully checked and adjusted as a unit after assembly. This unitary construction permits the use of short leads to minimize lead resistance.



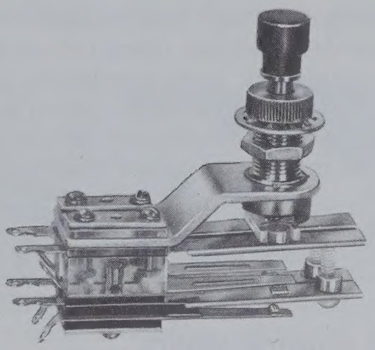
BINDING POSTS

Binding posts of co-axial construction are specially designed for applications where guarding is required to drain off stray currents which might affect the measuring circuit. These guarded-type binding posts have low-thermal, gold-plated copper terminals and acrylonitrile styrene copolymer insulation. They accommodate wire sizes up to No. 10 AWG. On some instruments, the terminals are recessed in a compartment provided with a hinged, magnetically-latched cover, to provide thermal and electrostatic shielding.



LOW-THERMAL KEYS

Special low-thermal keys connect the instruments to their associated null detectors, and in many instruments control the effective sensitivities of the null detectors. Errors which might be caused by residual emfs in the detector and circuit can be eliminated by use of a "Normal-Reverse" key. Gold-to-gold contact surfaces assure low thermal-generation (less than 0.1 μV under normal operating conditions). Keys are easily convertible from non-lockdown to lockdown, without disassembling, simply by loosening the knob, depressing the actuator shaft and giving it a quarter turn, then retightening the knob.



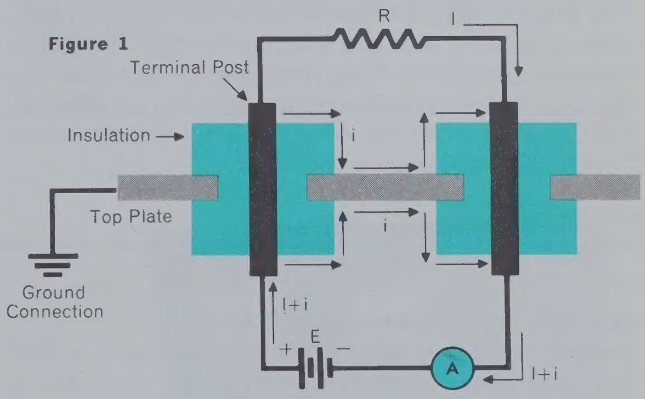
SHIELDING

Shielding, a common feature of construction on electrical instruments, refers to the grounding of the metal case and top plate, which serves as an electrostatic shield and diverts external charges that might pass through the measuring circuit. These charges may accumulate on the operator's body or originate from external apparatus, and are especially prevalent in a dry atmosphere.

GUARDING

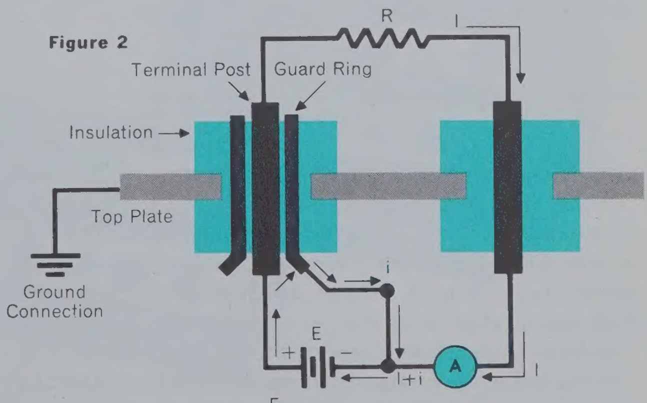
Guarding, a feature provided on many high-precision L&N instruments, refers to the use of special circuitry, insulated from ground, to provide freedom from adverse effects of leakage currents. The stray current is bypassed through a non-critical path so that it does not affect the accuracy of measurement. Figure 1 illustrates an unguarded circuit for measurement of a resistance R. The meter A is intended to measure the current I resulting from application of voltage E. Surface leakage current (i) bypasses the resistor (R) and passes through the meter A, causing an indication higher than the true magnitude of the current through the resistor (I). Figure 2 illustrates the principle of a guarded circuit. A guard ring surrounds the positive terminal post. The surface leakage is still present but is guided away from the meter to a non-critical return path. The guarding shown eliminates the effect of leakage current and the detector indicates only the current through the resistor. Guarding is especially important when measuring low voltages and when measuring high-value resistances, particularly when high humidity causes a reduction in normally high insulation resistance.

Figure 1



$R=\frac{E}{I}$ but detector is actually measuring I+i

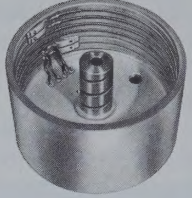
Figure 2



$R=\frac{E}{I}$ and detector measures I only

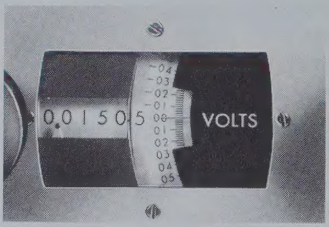
TWO-TURN SLIDEWIRE

A specially-designed slidewire used on some L&N portable potentiometers provides a 27.5″ slidewire in a case which is only 7″ deep. This slidewire is spirally-wound to utilize two full turns of the drum, providing twice as much resolution as would otherwise be possible.



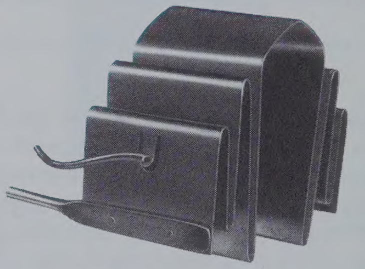
READOUT

Special consideration has been given to ease of readout on L&N instruments to facilitate operation and prevent the chance of misreading. Some instruments utilize a central-readout window with all digits lining up horizontally, and automatic positioning of the decimal. In other cases in-line readout is provided through windows above each dial.



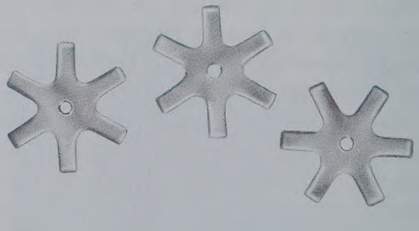
TECHNIQUE FOR ADJUSTING SHUNTS

Leeds & Northrup has developed a unique method for the fine adjustment of the resistance value of shunts. The potential leads are connected to two U-shaped tabs cut into opposite ends of the manganin strip. These tabs can be lengthened by filing. When one is lengthened, the distance between potential points—and thus the effective resistance–is increased. When the other is lengthened, the effective resistance is decreased.



EQUIPOTENTIAL TERMINAL JUNCTIONS

Another interesting L&N technique is the use of a copper "washer" with lead-connection points, equidistantly positioned around the circumference, for construction of a common terminal point. This method provides equalization of potential points—which cannot be precisely attained by a multiple-point soldered connection.



LOW-THERMAL CONSTRUCTION TECHNIQUES

Among the many construction techniques used at L&N to minimize thermal emf's are a balanced placement of connections, use of low-thermal solder, and selection of metals such as gold, copper, and manganin. Temperature equalization is further provided by the use of temperature-lagged cases, blocks, etc. Critical elements of circuits in high-precision instruments are often housed in temperature-controlled chambers.

LOW-IMPEDANCE CONSTRUCTION

Better detector sensitivity is obtained as the impedance presented to the detector is lowered. L&N designs bridges and ratio sets to utilize low-impedance circuits to obtain optimum detector sensitivity.

USE OF AUXILIARY CONNECTIONS

Auxiliary connections are utilized on some instruments for calibration purposes. The range on the 4287 Kelvin bridge, for example, can be extended with external standards; the Type K-5 Potentiometer provides auxiliary emf's by means of additional terminals and a rotary selector switch. Examples of this usage are for measurements of semiconductors or resistance thermometers.

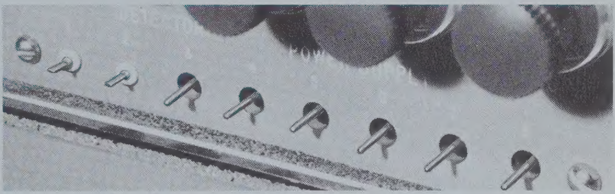
COMPATIBLE ACCESSORIES

Leeds & Northrup can provide all accessory equipment required for making specific types of measurements at the desired level of accuracy. Recommended accessories —resistance standards, galvanometers, electronic null detectors, power supplies, detector sensitivity keys, battery keys, thermocouples, resistance thermometers, conductivity cells and constant temperature baths—are listed in this catalog and fully described in appropriate sections.

CALIBRATION FEATURES

Special features on many L&N instruments improve convenience of calibration. For example, eight studs, which connect to precisely established internal calibration points, are mounted on the back terminal board of the 7556 Potentiometer. This eliminates removing the instrument from the case, and assures more accurate calibration by eliminating the effects of body heat and drafts on internal components.

Many L&N instruments provide self-calibration features. Type K-4 and K-5 Potentiometers utilize a build-up method of self-calibration, and the 4232 Wheatstone Bridge permits convenient cross-check of ratios.



The 7594 and 7594-2 Volt Boxes utilize the Silsbee and Gross method of volt box calibration (NBS Research Paper RP1419). L&N Calibration Procedures, available on high-precision instruments, are written by the designer of the instrument. We can supply all necessary calibration equipment.

MOUNTING ARRANGEMENTS

Various L&N instruments are provided in portable, bench and rack-mounting models, as well as complete facilities and consoles. Certain of these can be converted from a bench-top to a rack-mounting arrangement. The newly-designed cast-aluminum case available with bench-top Type K Potentiometers and the 4232 and 4737 Wheatstone Bridges provides retractable legs so that optimum face-plate angle (from the horizontal) can be obtained for a standing operator (30°), or a seated operator (50°).

LEEDS & NORTHRUP / WHEATSTONE BRIDGE FACILITY
GUARDED WHEATSTONE BRIDGE
GUARDED WHEATSTONE BRIDGE
GUARDED WHEATSTONE BRIDGE

GLOSSARY OF TERMS

ACCURACY—Closeness of approach of a measured quantity to true value of that quantity. (See "True Value".)

NOTE: The most commonly used index of accuracy is the possible deviation of the measured value from the true value. This includes evaluation of such items as: the precision of the measurement; known and possible errors in the values of physical standards used; known and possible errors resulting from intercomparison devices and techniques; and, when necessary, allowance for uncertainty of the value of the national standards.

CORRECTION—An increment which, when added algebraically to the indicated value, will give a better approximation to the true value of a measured quantity.

ERROR—The negative value of the correction.

GUARDING—The introduction of conducting surfaces at critical points within the circuit to intercept and appropriately divert leakage currents which would otherwise cause adverse effects or measurement errors.

IMPEDANCE, INPUT—The impedance presented by a device to the source.

IMPEDANCE, LOAD—The impedance presented to the output of a device by the load.

IMPEDANCE, OUTPUT—The impedance presented by a device to the load.

IMPEDANCE, SOURCE—The impedance presented to the input of a device by the source.

INTERFERENCE—An unwanted component of a signal or variable which obscures its information content.

INTERFERENCE, COMMON MODE—Interference which appears between measuring circuit terminals and ground.

INTERFERENCE, NORMAL MODE—Interference which appears between measuring circuit terminals.

INSTABILITY—An undesired change over a period of time, which change is unrelated to input, operating conditions, or load.

LETTER OF PERFORMANCE OR CONFORMANCE—A typed statement verifying that the instrument in question has been constructed in accordance with advertised specifications and has the accuracy claimed for it.

LIMIT OF ERROR—An accuracy index which indicates the *maximum expected* deviations of the true value from the measured value if all of the factors influencing the deviations act simultaneously and in the same direction. On new instruments, the limits of error are usually guaranteed not to exceed this maximum for one year.

NOTE: For convenience purposes, the limits of error are often expressed in proportional parts plus a residual dimensional term. To express the limits in dimensional terms only, the proportional parts must be converted to a dimensional term at a particular measurement level and then added to the residual term.

MEASUREMENT—The process of comparing an unknown value of a physical quantity (as associated with some material object or physical system) with physical standards of that quantity, or with a system of physical standards from which the quantity may be derived.

NOISE—(Electrical)—A form of interference introduced into a signal system by natural sources, which constitutes for that system an irreducible limit on its signal resolving capability. Noise is characterized by randomness of amplitude and frequency distribution.

OPERATING CONDITIONS—Conditions (such as ambient temperature, humidity, pressure, vibration, etc.) to which a device is subjected, but not including the variable measured by the device.

POWER CONSUMPTION—The maximum wattage used by a device within its operating range during steady-state signal conditions.

PRECISION—(Repeatability) (Reproducibility)—The closeness of agreement among a series of independent measurements of a single physical quantity under specified operating and ambient conditions.

NOTE: A commonly used index of precision when all the deviations act in a completely random fashion, is the square root of the average of the squares of the deviations of the individual measurements from the average value of the group of measurements.

PRIMARY ELEMENT (Sensor)—The first system element that responds quantitatively to the measured variable.

REPORT OF CALIBRATION. (As supplied by L&N.)

A typed report which includes calibration and/or correction data, the use of which will usually improve the accuracy of measurements. Such data are based on standards calibrated periodically by the National Bureau of Standards. The data supplied in the L&N Report of Calibration (barring damage or misuse of the product) are reliable to the confidence level given in the report for at least one year from the date of test. On certain new products, however, where sufficient long term history of stability has not been accumulated, the data supplied is reliable to the confidence level given only at the time of calibration. In this latter case, a qualifying statement is included in the Report of Calibration.

RESOLUTION—One switch step of the least significant dial or the interval between adjacent marked divisions on a continuously adjustable dial. When uncalibrated adjustments are provided, resolution is the smallest change which can be obtained by manipulation of the instrument controls.

SENSITIVITY (Null Detector)—The ratio of the magnitude of the quantity measured, under specified conditions, to the magnitude of its deflection. For example, a null detector, with a sensitivity of 1 μV/mm, will respond with a meter deflection of one millimeter when 1 microvolt is applied to the input under specified conditions.

STABILITY—The quality of invariance with time. The measure of stability is change in value per unit of time.

TRUE VALUE—The value of a physical quantity that would be attributable to a material object or physical system if that value could be determined without error.

B

STANDARDS

Introduction B-1
Resistance Standards B-6
Voltage Standards B-16
Capacitance Standards B-17
Inductance Standards B-18
Temperature Standards B-20

STANDARDS: ELECTRICAL & TEMPERATURE

Leeds & Northrup provides you with a wide choice of fixed and adjustable standards—resistors, standard (potential) cells, capacitors and inductors, for use as reference standards for checking and calibrating, or as working standards with ratio devices in d-c and a-c bridge measurements and in potentiometric measurements. For most applications you will find a standard listed here to cover the desired range, within the accuracy required, for measurements at high or low values of resistance or impedance. L&N also manufactures temperature standards and a constant-temperature bath for applications which require precise temperature control. If you have need for a standard not listed here, please consult us about the construction of a special one.

THE L&N LIMIT OF ERROR

Each L&N standard can be depended upon to retain its stated value. Since the pertinent properties of the materials used are not completely invariable, and even the best standards are not perfectly stable, a margin is allowed between the accuracy of adjustment and guaranteed limit of error. To assure reliability, only that limit of error is guaranteed which a given standard can be expected to maintain, in normal use, for a long period of time. Certain of the more precise L&N standards can be certified, if you desire, by the National Bureau of Standards.

A SIXTY-YEAR REPUTATION FOR RELIABILITY — Because we realize that your confidence in the accuracy and stability statement accompanying any standard is based on the experience, skill and reputation of the manufacturer, we at Leeds & Northrup exert every effort to deserve this confidence.

For example, there are many factors which contribute to our reputation as a reliable manufacturer of highest precision resistance standards. For over 60 years, L&N has had extensive experience in the theory and application of precision resistors. During this time a continuous program of research has enabled us to develop many improvements to contribute to the advancement of the "state-of-the-art". Painstaking precautions are observed in intercomparing the comprehensive array of standards maintained by our own Standards Laboratory, which are regularly checked by NBS. By maintaining historical records on our own prime standards over many years, we have acquired an extensive knowledge of stability, its predictability and its improvement. Some of these standards have been recertified regularly by the NBS for over 30 years.

Also contributing to our reputation are our long-time cooperation in the design and development of precision calibration tools with many standards laboratories in both private industry and government, and our experience in the design, manufacture and application of related measuring equipment which form the basis for our complete understanding of the total resistance-measurement concept.

RESISTANCE STANDARDS

Since January 1, 1948, the "absolute ohm" has been determined by extremely precise measurements of length, mass and time. The "international ohm", which was legal prior to 1948, is equal to 1.000 495 absolute ohms; the absolute ohm is the basis for the legal unit of resistance. For a period of time after the changeover, precise instruments were marked "abs", indicating that their resistors were adjusted in terms of the absolute ohm. The United States legal ohm is maintained at the National Bureau of Standards in terms of the mean resistance of 10 very carefully constructed 1-ohm resistors, with which other resistors may be compared to serve as secondary standards. These secondary standards are usually of the NBS type, in which resistance wire is wound on a spool and sealed in oil in a metal case. Such resistors serve as standards for use in laboratories where other resistors are to be adjusted or where other precise electrical measurements are made.

L&N resistors are used in a variety of electrical measurements, both as fixed and adjustable elements, and range from 20,000-ampere shunts weighing over six hundred pounds, with a resistance of 2.5 microhms, to resistors weighing a fraction of an ounce, with a value of 1 megohm. Accuracy can range from one part in a million for a 1-ohm standard certified by NBS to a shunt certified to one part in a thousand or less. Resistors may be permanently connected into electrical circuits to provide a fixed resistance, or may be assembled into resistance boxes or decades where they are connected into switching mechanisms so that the resistance between the terminals of the box can be varied by known amounts. For example, a four-decade resistance box having decades of ten 1-ohm resistors, ten 10-ohm resistors, ten 100-ohm resistors and ten 1000-ohm resistors may be adjusted to provide resistance values from 0 to 11,110 ohms in 1-ohm steps.

L&N manufactures resistors which meet virtually every need you may have for standards in bridge measurements of resistance and impedance, for shunts in potentiometric measurements of current and for stable ratio devices. Both fixed resistors and adjustable resistance boxes are available in a choice of resistance values. Fixed resistors for mounting inside instruments are available as small as 0.01 ohm. For resistance change, the Waidner-Wolff circuit provides changes down to 1 microhm.

Figure 1 shows the variety of L&N Resistance Standards available in various classifications, based on resistance value, accuracy, and type (Basic Reference Standard, Fixed, Adjustable, and Special-Purpose).

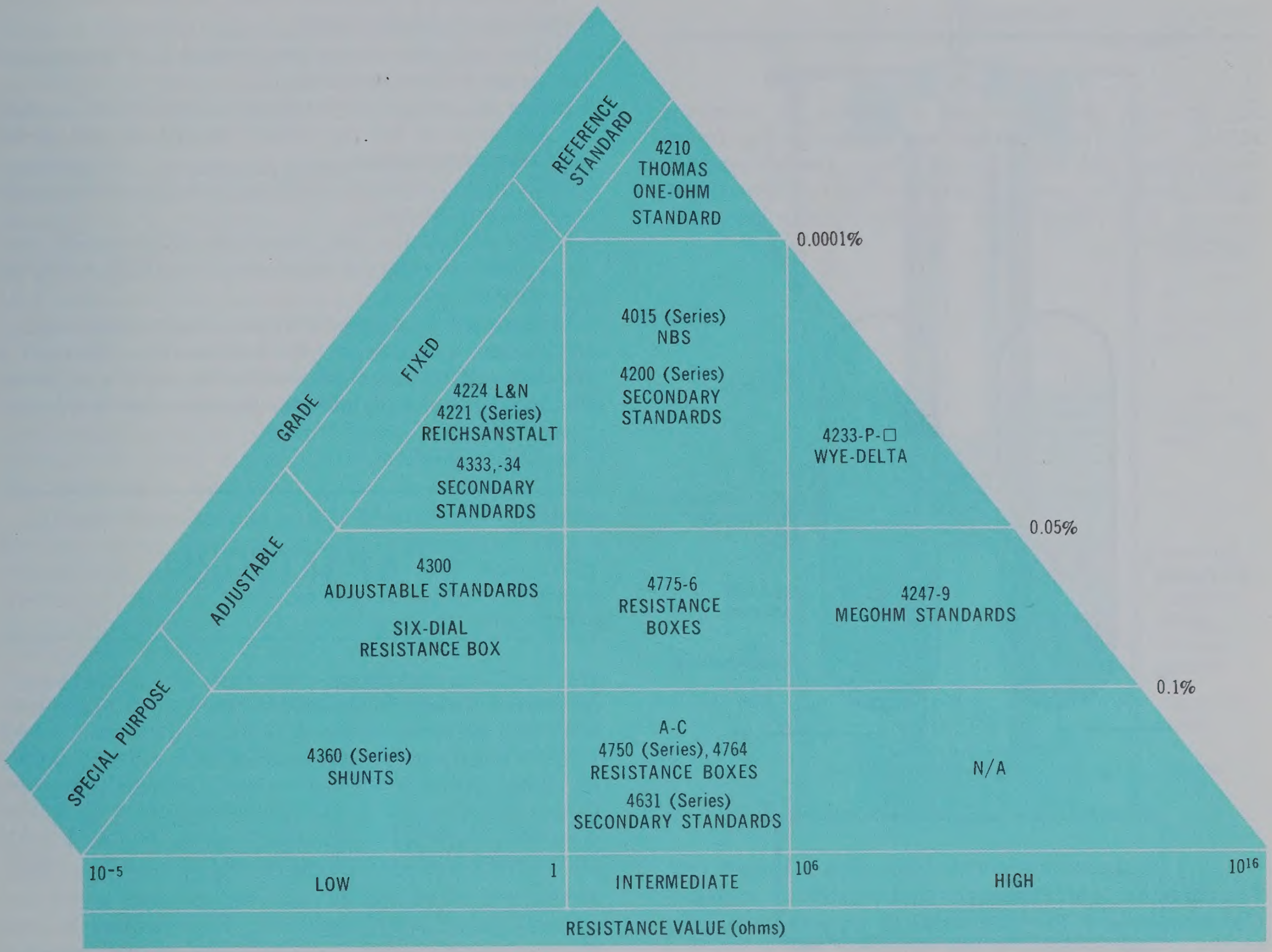

REFERENCE STANDARD
4210 THOMAS ONE-OHM STANDARD
0.0001%
GRADE
FIXED
4224 L&N
4221 (Series) REICHSANSTALT
4333,-34 SECONDARY STANDARDS
4015 (Series) NBS
4200 (Series) SECONDARY STANDARDS
4233-P-□ WYE-DELTA
0.05%
ADJUSTABLE
4300 ADJUSTABLE STANDARDS
SIX-DIAL RESISTANCE BOX
4775-6 RESISTANCE BOXES
4247-9 MEGOHM STANDARDS
0.1%
SPECIAL PURPOSE
4360 (Series) SHUNTS
A-C 4750 (Series), 4764 RESISTANCE BOXES
4631 (Series) SECONDARY STANDARDS
N/A
10⁻⁵
LOW
1
INTERMEDIATE
10⁶
HIGH
10¹⁶
RESISTANCE VALUE (ohms)

Fig. 1—L&N Resistance Standards

DESIGN AND CONSTRUCTION — L&N resistors are constructed of the best materials for each specific purpose based on the results of thorough investigation and extensive experience. Special manganin wire—an alloy of copper, manganese and nickel—is manufactured under carefully controlled conditions to meet L&N's exacting metallurgical and electrical specifications. The properties of this wire include: high specific resistance (45 to 50 microhm-cm); low temperature coefficient of resistance, passing through zero at selected points between 20 C and 40 C; and a small thermal emf against copper (about —1.5 microvolts per degree C).

In general, resistors primarily for d-c measurements are made of specially insulated wire, wound bifilar on ceramic or enameled-metal spools. Resistors for a-c measurements are constructed by weaving the resistance wire into special patterns and mounting on ceramic spools. For special purposes, other designs are employed. Close attention is given to leads and insulation to insure reproducibility of value.

After treatment to assure permanence of resistance, each unit is adjusted to its nominal resistance value, within the required accuracy, by comparison against a working standard. (The working standards are checked periodically with our primary standards, which in turn are calibrated at frequent intervals by the National Bureau of Standards.) Each resistor is then thoroughly aged and rechecked or readjusted after being mounted.

Because total resistance between the binding posts of a resistance box or the rheostat arm of a Wheatstone bridge includes not only that of the resistors but also of internal connections and of switch contacts, great care is exercised in design and construction to minimize this lead and contact resistance.

STANDARD (POTENTIAL) CELLS

For accurate measurements of voltage, a reference voltage is required. This may be a standard cell or Zener-diode-referenced power supply. Since the accuracy of standard cells is usually greater than that of Zener-diode supplies, a standard cell is normally used for laboratory measurements.

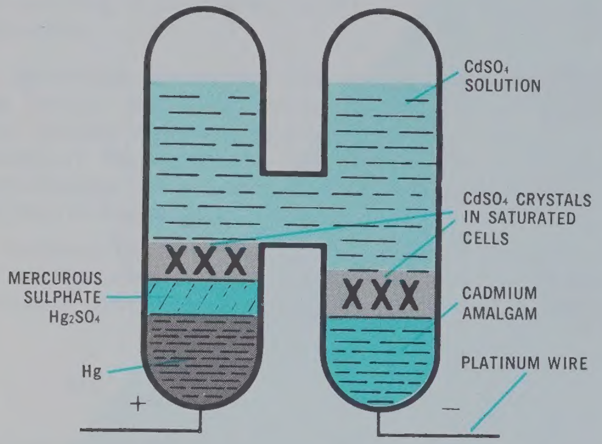

$CdSO_4$ SOLUTION
$CdSO_4$ CRYSTALS IN SATURATED CELLS
MERCUROUS SULPHATE Hg_2SO_4
CADMIUM AMALGAM
Hg
PLATINUM WIRE
+
−
XXX
XXX

Fig. 2— Saturated Standard Cell.

Figure 2 illustrates the construction of a standard cell. The container is an H-shaped glass vessel with sealed-in platinum wires at the lower ends of the vertical legs for electrical connections. In the saturated cell (shown) a surplus of $CdSO_4$ crystals is placed in the cell to maintain saturation, while in the unsaturated cell, the solution is unsaturated at room temperatures.

SATURATED CELLS—The saturated cell is the basic standard. These cells have a high degree of uniformity, with very small voltage variation between individual cells. Because of the 3.3 μV/0.01 C Δt between legs, it is important to keep the entire cell at uniform temperature. At 20 C, the voltage-temperature coefficient is about −40 μV/C. Since saturated cells are slow to accommodate to changes in temperature, hysteresis results if the cell is heated and cooled; hence close temperature regulation by means of an oil or air bath is required.

Saturated standard cells are measured by the NBS to 0.1 μV at a stated temperature, the value accurate to 1 μV, for Reports of Calibration. If recommended procedures for use and storage are followed, instabilities greater than 2 or 3 μV per year are rare. Saturated cells are made in shippable and non-shippable types. The latter contains no septum, therefore may not be tipped more than 30°. They must be hand-carried from manufacturer to calibration facility to user.

UNSATURATED CELLS—The unsaturated cell is similar in construction to the saturated cell except that it contains no $CdSO_4$ crystals, and the solution is unsaturated at room temperature. Typical rate of drift is −3 μV/month. A retaining member is used over each electrode to hold the material in place against ordinary motion, so that the cell is portable. A lower temperature coefficient (−3 μV/C) permits use under normal ambient temperature conditions. Overall accuracy for unsaturated cells is normally assumed to be ±0.005% (50 ppm).

The following precautions should be taken when using either type of standard cells:

1) The cell should not be exposed to temperatures below 4 C nor above 40 C.
2) Abrupt changes in temperature should be avoided.
3) All parts of the cell should be maintained at the same temperature.
4) Current in excess of 0.0001 ampere should never pass through the cell.
5) The emf of the cell should be redetermined periodically at intervals adequate to establish a stability pattern.

For use with L&N potentiometers requiring an external cell, Leeds & Northrup lists unsaturated cells and a standard voltage reference which combines four saturated standard cells in a portable temperature-controlled case.

CAPACITORS

For use as standards of comparison in a-c bridge measurements at power, audio, and higher frequencies, L&N provides hermetically-sealed capacitors. These standard L&N capacitors cover a wide range of applications. However, as the diversity of a-c bridge measurements creates a substantial demand for special ones, we can provide capacitance standards designed to meet specific needs.

INDUCTORS

A selection of fixed and adjustable inductors is provided as standards of inductance in a-c bridge measurements up to 1000 hertz. For higher frequencies, and for precision measurements even at the lower frequencies, we recommend that inductance be measured in terms of resistance and capacitance, using bridges.

The fixed inductors are toroidal coils, mounted on phenolic plates and enclosed in ventilated phenolic cases; in applications up to 1000 hertz, they are practically immune to stray-field errors, cause no objectionable external fields, and show no appreciable increase in resistance.

Brooks Inductometers can be supplied for varying the self-inductance of a circuit, or the mutual inductance between two circuits. The standard instruments have self-inductance scales only. However, on special request they can be constructed with scales calibrated in degrees, mutual inductance, phase angle or power factor, with two scales.

TEMPERATURE STANDARDS

Leeds & Northrup manufactures a unique selection of equipment to provide temperature standards and extremely stable temperature environments for the calibration and precise comparison of a variety of standard measuring equipment.

TEMPERATURE STANDARDS (FIXED)—The 8411 Fixed Temperature Standard is used to provide a known reference temperature for calibration of resistance thermometers or thermocouples. The fixed temperature points provided by this equipment are the freezing points of indium, tin, lead, cadmium, zinc, antimony and aluminum. The high-purity metal of the desired freezing point is contained in a freezing-point cell which is housed in a temperature-equalizing block as shown in Figure 3. In operation, when the metal sample reaches its freezing point, the temperature remains constant for an extended period of time, permitting numerous calibrations and tests at this temperature "plateau."

L&N also manufactures an 8410 Steam-Point Apparatus for calibrating thermometers by comparison with a thermometer certified by the NBS. The comparison method is used to eliminate the difficulty of precisely controlling pressure (the coefficient of temperature change with pressure of steam is 28 C/atm.)

TEMPERATURE STANDARDS (ADJUSTABLE)—The 9009 Thermocouple Calibration Furnace is similar in construction to the 8411 except that it utilizes an equalizing block suitable for the required temperature range and a checking thermocouple in place of the freezing-point cell.

The 8401 Constant-Temperature Bath is designed to facilitate the precise comparison of saturated standard cells, resistance standards, electrolytic conductivity cells and other laboratory devices, as well as for the calibration of thermometers, thermistors and other temperature-sensitive devices within its range. The culmination of thirty years' experience in the design of temperature baths, the 8401 utilizes a unique flow system to provide a stable, extremely uniform temperature environment.

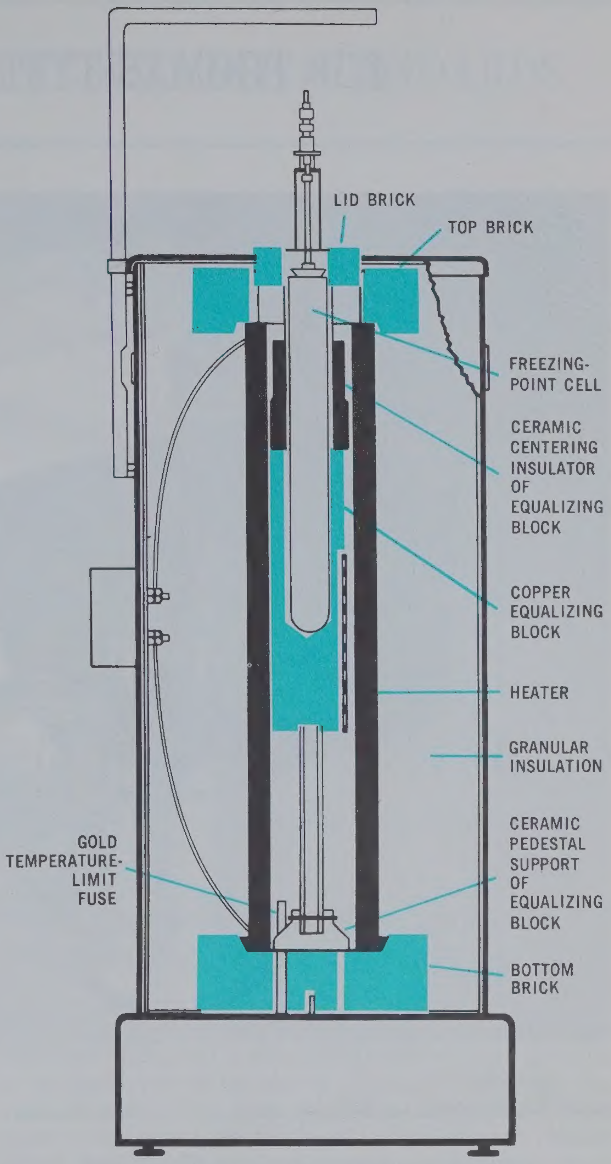
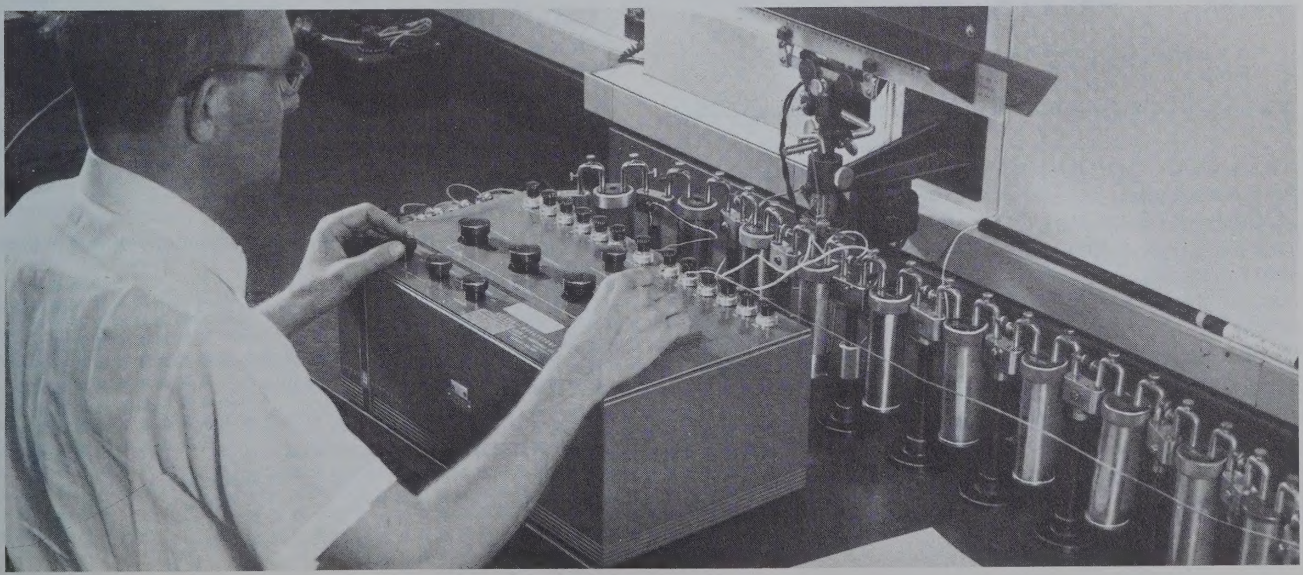

LID BRICK
TOP BRICK
FREEZING-POINT CELL
CERAMIC CENTERING INSULATOR OF EQUALIZING BLOCK
COPPER EQUALIZING BLOCK
HEATER
GRANULAR INSULATION
CERAMIC PEDESTAL SUPPORT OF EQUALIZING BLOCK
BOTTOM BRICK
GOLD TEMPERATURE-LIMIT FUSE

Fig. 3—Cross-section view of furnace, equalizing block, and freezing-point cell.



4210 THOMAS-TYPE ONE-OHM STANDARD

PRIME STANDARD FOR USE IN MAINTAINING VALUE OF THE OHM

Measured value accurate to one part per million

NBS report of calibration furnished

This resistor was developed by Dr. J. L. Thomas* at the National Bureau of Standards for use as a reference standard of resistance in laboratories requiring extremely high accuracy. In the L&N adaptation, the resistance element consists of specially selected bare manganin wire, wound bifilar, thoroughly annealed, and mounted without stress on an insulated brass cylinder. Current and potential leads are brazed and the resistance between potential leads is adjusted to 1 ohm.

The resistor is hermetically sealed in the circular space between its mounting cylinder and an outer brass shell. Leads are brought out through metal-to-glass seals. Its measured value—in terms of the Legal Ohm as maintained at NBS—is given to 1 part in 10 million (0.000 01%) at 25 C. The standard is adjusted, as a 4-terminal resistor, to one ohm and is supplied in a special carrying case containing a foam polystyrene form to hold the unit firmly in place.

SPECIFICATIONS

RESISTANCE—1 ohm.

LIMIT OF ERROR—Adjusted within 5 ppm (0.0005%) of nominal value at 25 C. NBS compares each resistor to the Legal Ohm as maintained at the Bureau. The NBS measured value is given to 1 part in 10 million (0.000 01%) at 25 C, the stated value accurate to one ppm (0.0001%). An NBS Report of Calibration and an L&N Report on the temperature coefficient of each resistor are included in the price.

STABILITY—Changes in resistance typically do not exceed 1 ppm per year.

TEMPERATURE COEFFICIENT—Included with each standard is an L&N Report stating the Alpha and Beta values used to calculate the resistance of the standard at a temperature other than the temperature of calibration.

CURRENT RATING—0.1 A when immersed in stirred oil.

CONNECTIONS—Four-terminal, current/potential type. Resistance of current and potential leads, approximately 0.0011 to 0.0013 ohm each.

CASE—7" (w) x 6½" (h) x 3¾" (OD); weight approx. 3 lb.

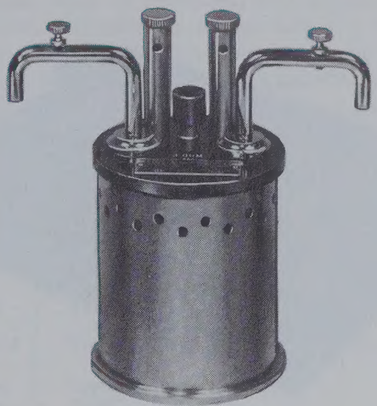
PRICE—$505.00.

**NBS Research Paper 1692.*

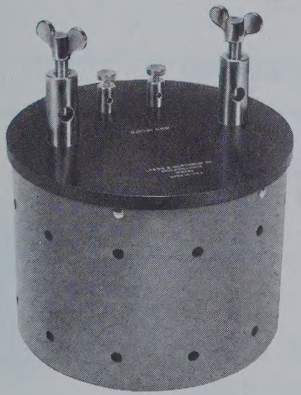
422☐-B REICHSANSTALT-TYPE RESISTANCE STANDARDS

LOW-RESISTANCE COMPARISON STANDARDS (0.001 TO 0.1 OHM)

These resistors are used in the accurate measurement of current with a potentiometer, and as standards for comparison in low-resistance measurements. The design of these resistors is based on those developed at the Reichsanstalt. In the 4221, the manganin resistor is bifilar wound. In the 4222 and 4223, a strip or sheet of manganin is supported between two terminal rods. The manganin elements are enameled after final adjustment. To obtain the current-carrying capacities listed in the table, these resistors should be immersed in stirred oil baths. An L&N Report of Calibration is supplied which gives (1) temperature coefficient data and (2) measured value at 25.0 C with accuracy as indicated in the table.



4224-B-A☐☐☐ L&N-TYPE 0.0001-OHM RESISTANCE STANDARD



FOUR-TERMINAL RESISTANCE STANDARDS WITH HIGH CURRENT CAPACITY

Similar to the Reichsanstalt resistors, these resistors are designed to be used in measuring relatively high currents, or as four-terminal resistance standards with high current capacity. They also provide a sub-multiple-of-ten lower resistance than the lowest Reichsanstalt resistor listed. An L&N Report of Calibration is supplied which gives (1) temperature coefficient data and (2) measured value at 25.0 C with accuracy as indicated in the table.

Type	Integral Standards			Intermediate Standards		Wattage Rating	Limit of Error†			Size	Price
	List Number	Resistance (Ohms)	Current Rating (Amperes)	List Number*	Resistance (Ohms)		Adjustment to Nominal Value	Measured Value** Stated to:	Accuracy of Measured Value***		
L&N	4224-B-A150	0.0001	150	–	–	–	±0.01%	±0.001%	±0.005%	7″ x 7½″ x 3½″	$ 650.00
	4224-B-A300		300							10½″ dia. x 12″ (h)	1070.00
Reichsanstalt	4223-B	0.001	30 100	–	–	1 Watt 10 Watts	±0.005%	±0.0001%	±0.002% (30 amps) ±0.05% (100 amps)	7″ x 7½″ x 3½″; 3 lb	450.00
	4222-B	0.01	10 30	4222-B-X ☐	0.002, 0.005, 0.02 or 0.05		±0.003% ****	±0.0001%	±0.001%**** (for smaller current figure) ±0.05% (for larger current or wattage fig.)	7″ x 6″ x 3⅝″ 2 lb	4222-B 150.00 4222-B-X 200.00
	4221-B	0.1	3 10	4221-B-X ☐	0.2, 0.5, 1.0, 2.0, 5.0 or 10						4221-B 150.00 4221-B-X 225.00

**To specify desired resistance, add the basic resistance multiplier in the blank following the letter "X". Examples: 4222-B-X5 identifies a 0.05-ohm standard (five times the basic resistance of 0.01-ohm). For "intermediate" values of resistance that do not adhere to the above listings or increments, consult your nearest L&N office.*

***Temperature Coefficients—For most standard resistors, the resistance at any temperature in the interval 20 to 30 C does not differ from the resistance at 25 C by more than 50 ppm. Within the interval 15 to 35 C, the change of resistance with temperature for a manganin resistor is accurately expressed by the equation:* $R_t = R_{25}[1 + \alpha(t-25) + \beta(t-25)^2]$ *where* R_t *is the resistance at t C,* R_{25} *is the resistance at 25 C and* α *and* β *are constants included in the report data. Experience shows that the coefficients* α *and* β *do not change appreciably with time and hence need to be determined only once.*

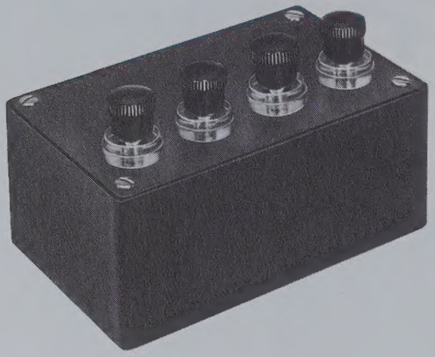
All resistors listed are supplied with such temperature coefficient data.

****At time of calibration. Measured value will remain stable for a period of one year within 10 ppm for standards 0.01 ohm and above; 20 ppm below 0.01.*

*****Applies to integral standards only. For intermediate values, adjustment is ±0.005% and accuracy is ±0.002% for smaller wattage figure.*

†The value of resistance given is in terms of the U.S. Legal Unit and is traceable to a set of reference standards maintained by L&N and calibrated at regular intervals by the NBS. Some of these reference standards have been recalibrated regularly by the NBS for over 30 years.

4333, -34 SECONDARY-STANDARD RESISTORS



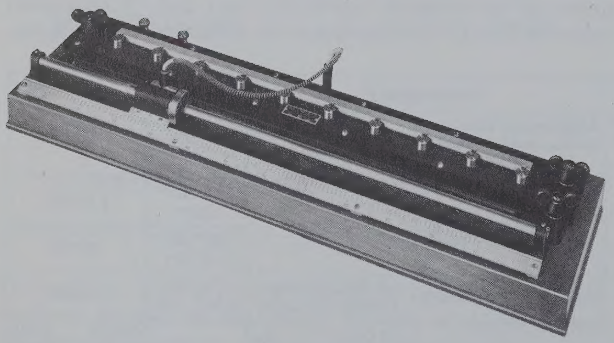
FOR USE AS WORKING STANDARDS OR RANGE-EXTENDING OF 4287 KELVIN BRIDGE

The 4333 and 4334 can be used as working-standard resistors for general laboratory application, or as range-extending standards for the 4287 Kelvin Bridge. The resistance element consists of a strip of manganin supported between the terminals. Connections are made to four acrylonitrile-styrene binding posts.

List No.	Resistance, Absolute Ohms	Current Rating, Amperes	Limit of Error	Case	Price
4333	0.001	30	±0.02%	3¾″ x 5½″ x 3¾″ Weight approx. 1 lb. 4 oz.	$220.00
4334	0.0001	30	±0.2%		260.00

Low-Value Resistance Standards (Adjustable)

4300 ADJUSTABLE STANDARD



PRECISELY ADJUSTABLE LOW-VALUE RHEOSTAT

This adjustable low-resistance standard is used primarily as a rheostat arm with the 4320 Kelvin Bridge Ratio Box to form a general-purpose Kelvin bridge for making low-resistance measurements. The unit consists of a large-diameter calibrated bar and nine fixed resistors mounted on a mahogany base. This arrangement is equivalent to having a graduated bar ten times as long as the one used. It also provides a precision of setting correspondingly greater than if the bar alone provided the total resistance of the standard.

List No.	Total Resistance	Adj. Std.	Fixed Standard	Limits of Error		Current Rating Amp.	Case	Price
				Fixed Std.	Adj. Std.			
4300	0.0101 ohm	0.0011 ohm; 110 divisions continuously adjustable with 1 microhm readability	9 x 0.001 ohm, plug - and - block controlled in series with bar	Up to 0.005 ohm, ±2 microhms; above 0.005 ohm, ±0.04%	±2 microhms	For 10-minute period: 50 in entire standard, 150 in bar alone. For continuous duty: 30 in entire standard, 90 in bar alone.	30⅞″ x 8⅞″ x 6⅞″; weight approx. 18 lb.	$1250.00

4790 SIX-DIAL MICROHM RESISTANCE BOX

FOR COMPARISON OF MUELLER-BRIDGE AND OTHER LOW-VALUE DECADES

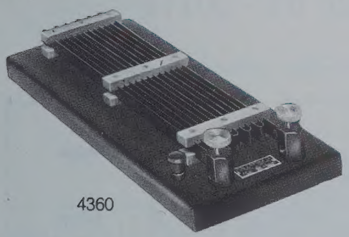
Especially useful in the calibration of low-value decades, this six-dial resistance box utilizes Waidner-Wolff decades, Type 31 switches, and bifilar-wound resistors. Switches and resistors are housed in a metal box which is mounted in a cork-lined outer box to further improve thermal stability (temperature coefficient is less than 10 ppm/°C at room temperature). An L&N Report of Calibration is available.

List Number	Decades, Ohms	Residual Resistance, Ohms	Limits of Error			Wattage Rating	Dimensions	Price
			Without Report of Calibration	With* Report of Calibration				
				Dial	Error			
4790	(−1 to 10)(0.1 + 0.01 + 0.001 + 0.0001 + 0.00001 + 0.000001) (Total resistance change of approx. 1.1 ohms in steps of 1 μohm)	10	±(0.05% + 10 μohm)	First	20 μohm	0.15	19″ (l) x 5″ (w) x 7¼″ (h)	$2950.00
				Second	10 μohm			
				Other Four	1 μohm (each)			

In terms of accuracy of resistance change above residual.

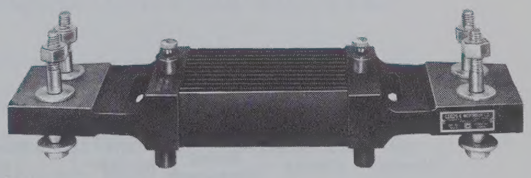
Low-Value Resistance Standards (Special Purpose)

4360-SERIES SHUNTS



4360

4363



4369, 4372, 4375

FOR MEASUREMENTS OF LARGE CURRENTS

These low-resistance standards or shunts are primarily for use in accurate measurements of large currents by the potentiometric method. They may be used as comparison standards for measuring resistance by either the potentiometric or the adjustable-ratio Kelvin-bridge method. The nominal resistance is that between the potential terminals.

These resistors are designed to have ample radiating surface for operation in air at ordinary room temperatures at their rated current-carrying capacities. They are sized so that operating temperature approximates peak temperature (zero temperature coefficient point) of special grade of Manganin used for L&N shunts. A resistor of this type may be used in place of the Reichsanstalt type, where ±0.04% limit of error is satisfactory.

The 4360, 4361 and 4363 resistors consist of a continuous strip of manganin in one or more folds, held in position by spacers. The other shunts are made up of parallel strips of this material between heavy copper terminals. They differ in the number and dimensions of the strips needed to obtain the required resistance and current-carrying capacity. All are designed to provide ample contact with bus bars or corresponding parts of current circuits. An L&N Report of Calibration is available (add suffix "-B").

List Number	Resistance, Absolute Ohms	Current Rating, Amperes	Limit of Error	Dimensions		Price	Add for Suffix "-B"
4360	0.1	15	±0.04% when cooled by air at ordinary room temperature.	15″ x 7″ x 3½″	3 lb	$128.00	$125.00
4361	0.01	100		20″ x 8″ x 7½″	15 lb	400.00	140.00
4363	0.001	300		18¾″ x 6½″ x 9½″	13 lb	360.00	140.00
4364	0.001	500		36″ x 5½″ x 5″	25½ lb	550.00	175.00
4369	0.00004	1500		20⅞″ x 4⅞″ x 4″	35½ lb	600.00	175.00
4372	0.00002	2000		20⅞″ x 4⅞″ x 4″	35½ lb	650.00	200.00
4375	0.00001	3000		20⅞″ x 4⅞″ x 4″	35½ lb	700.00	200.00

4015-SERIES NBS-TYPE RESISTANCE STANDARDS

100 OHMS
CAT 4030-B
LEEDS & NORTHRUP CO.
PHILA. PA. MADE IN U.S.A.

FOR USE AS 0.1 TO 1,000,000 OHM STANDARDS IN INDUSTRIAL, RESEARCH AND EDUCATIONAL LABORATORIES

These resistors are designed for use as standards in industrial, research and educational laboratories. Lower-value resistors are made of selected manganin wire, wound bifilar on metal spools, stress-relieved and aged to assure stability. In the higher values, woven manganin elements are used (except 4050-B which is of woven Evanohm). The coil is immersed in moisture-free oil within a metal container sealed with a molded epoxy head which provides an excellent oil-seal as well as an insulation of better than 10^{14} ohms. This construction permits immersion of the complete unit in oil for better temperature equalization and higher current rating. Limits of error for the nominal values listed in the table apply under conditions of normal use for one year after date of shipment. Intermediate values of resistance other than those listed can be provided (see table). An L&N Report of Calibration is supplied which gives (1) temperature coefficient data and (2) measured value at 25.0 C. (4-terminal values on resistors up to and including 10 ohms; 2-terminal values on resistors over 10 ohms.) The 4015-B is supplied with both 2- and 4-terminal values.

Type	Integral Standards			Intermediate Standards		Wattage Rating	Limit of Error†			Size	Price
	List Number	Resistance (Ohms)	Current Rating (Amperes)	List Number*	Resistance (Ohms)		Adjustment to Nominal Value	Measured Value** Stated to:	Accuracy of Measured Value***		
National Bureau of Standards	4015-B	0.1	3	—	—	1 Watt	±0.05%	±0.01%	±0.05%	4″ x 7″ x 1⅞″	$57.00
	4020-B	1	0.3 1.0	4020-B-X ☐	2 to 9 ohms in increments of 1 ohm	0.1 Watt 1 Watt	±0.003% ****	±0.0001%	±0.001%**** (for smaller current figure) ±0.02% (for larger current or wattage figure)		4020-B 57.00 4020-B-X 80.00
	4025-B	10	0.1 0.3	4025-B-X ☐	15 to 95 ohms in increments of 5 ohms						4025-B 52.00 4025-B-X 75.00
	4030-B	100	0.03 0.1	4030-B-X ☐	110 to 990 ohms in increments of 10 ohms						4030-B 52.00 4030-B-X 75.00
	4035-B	1000	0.01 0.03	4035-B-X ☐	1100 to 9900 ohms in increments of 100 ohms						4035-B 52.00 4035-B-X 75.00
	4040-B	10,000	0.003 0.01	4040-B-X ☐	11,000 to 99,000 ohms in increments of 1000 ohms						4040-B 57.00 4040-B-X 100.00
	4045-B	100,000	0.001 0.003	—	—		±0.005%				75.00
	4050-B	1,000,000	0.0003	—	—	0.1 Watt		±0.0001%	±0.002%		80.00

**To specify desired resistance, add the basic resistance multiplier in the blank following the letter "X". Examples: 4020-B-X5 identifies a 5-ohm standard; 4030-B-X5 a 500-ohm standard, 4035-B-X7.5 a 7500-ohm standard, etc. For "Intermediate" values of resistance that do not adhere to the above listings or increments, consult your nearest L&N office.*

***Temperature Coefficients—For most standard resistors, the resistance at any temperature in the interval 20 to 30 C does not differ from the resistance at 25 C by more than 50 ppm. Within the interval 15 to 35 C, the change of resistance with temperature for a manganin resistor is accurately expressed by the equation:* $R_t = R_{25}\,[1 + \alpha\,(t - 25) + \beta\,(t - 25)^2]$ *where R_t is the resistance at t C, R_{25} is the resistance at 25 C and α and β are constants included in the report data. Experience shows that the coefficients α and β do not change appreciably with time and hence need to be determined only once.*

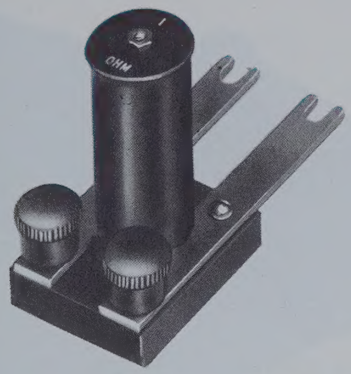
All resistors listed are supplied with such temperature coefficient data.

****At time of calibration. Measured value will remain stable for a period of one year within 10 ppm for standards up to 10K ohms; 20 ppm above 10K.*

*****Applies to integral standards only. For intermediate values, adjustment is ±0.005%, and accuracy is ±0.002% for smaller wattage figure.*

†The value of resistance given is in terms of the U.S. Legal Unit and is traceable to a set of reference standards maintained by L&N and calibrated at regular intervals by the NBS. Some of these reference standards have been recalibrated regularly by the NBS for over 30 years.

4200-SERIES SECONDARY RESISTANCE STANDARDS



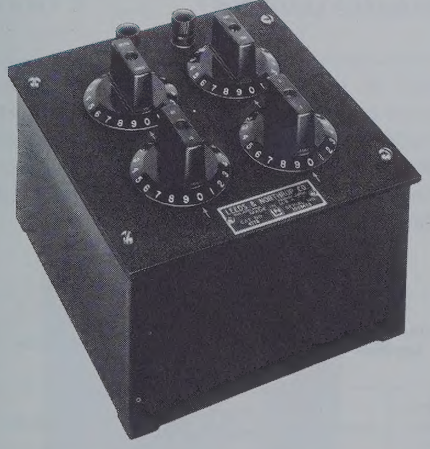
WORKING STANDARDS OF MODERATE ACCURACY

The 4200 Series Secondary Resistance Standards are fitted with two-terminal, strap and binding-post-type connections. An L&N Report of Calibration is available (add suffix "-B").

List No.	Resistance, Absolute Ohms	Current Rating, Amperes	Limit of Error	Case	Price
4205	1	1.0	±0.05%	3⅝" x 1¾" x 3¼" weight approx. 3 oz.	$50.00; for "-B", add $20.00
4206	10	0.3			
4207	100	0.1			
4208	1000	0.03			
4209	10,000	0.01			

Intermediate-Value Resistance Standards (Adjustable)

4775, -76 ENCLOSED-SWITCH RESISTANCE BOXES



INEXPENSIVE STANDARDS OF MODERATE PRECISION

Suitable for commercial power frequency a-c as well as d-c

The 4775 and 4776 Resistance Boxes are designed for general use in d-c circuits where an error of 0.1% is acceptable, such as making measurements with the L&N Students' Potentiometer. Moderate cost results from construction economies such as the use of only five resistors in each dial, connected to provide a zero position, and nine equal steps of resistance change for each 180 degrees of rotation of the switch.

List Number	Resistance, Ohms	Decade Steps	Current Rating, Amperes		Limit of Error	Dimensions	Price
			Highest Decade in Use:	Amperes			
4775	9999	9(1 + 10 + 100 + 1000)	0.1 1.0 10.0 100.0 1000.0	1.6 0.5 0.16 0.05 0.016	Resistance change from zero setting, measured across binding posts, equals dial settings ±(0.1% + 0.01 ohm)*	5⅝" x 6⅛" x 4⅜" weight 4 lb	$98.00
4776	999.9	9(0.1 + 1 + 10 + 100)					

**Statement assumes that box is in regular use, or that dials will be rotated before box is put into use after a period of idleness. D-c resistance with dials at zero does not exceed 0.03 ohm.*

4750-SERIES SHIELDED A-C RESISTANCE BOX

PROVIDES STANDARDS OF RESISTANCE FROM D-C THROUGH HIGH FREQUENCIES

Totally enclosed construction

Switches provide low, stable contact resistance

Terminals feature high insulation resistance

Electrostatic shielding

Widely used in research and production testing, the 4754, 4755 and 4756 are moderate accuracy a-c resistance boxes providing standards of resistance from d-c through high frequencies. Features include switches that provide low, stable contact resistances, totally enclosed construction to reduce maintenance, electrical shielding and gold-plated terminals for corrosion resistance mounted on polystyrene bases for high insulation resistance. An L&N Report of Calibration is available (suffix "-B").

4764 SHIELDED A-C RESISTANCE BOX

ADJUSTABLE STANDARD OF RESISTANCE USED WITH A-C BRIDGES AT AUDIO AND HIGHER FREQUENCIES

Idle resistors completely disconnected—eliminates effective capacitance

Electrostatic shielding

Providing an adjustable low-reactance standard of resistance, the 4764 Resistance Box is used in research for precise measurements with a-c bridges at audio and higher frequencies. This resistance box is designed to have essentially constant inductance and capacitance through the use of single-resistor decade construction. Special construction permits connection of only one resistor of each decade at any time. This eliminates effective capacitance of the unused resistors and permits no variation in the geometric configuration of the inductive loop. Electrical shielding is provided by an aluminum case and metal top-plate. An L&N Report of Calibration is available (suffix "-B").

List Number	Total Resistance, Ohms	Decade Steps	Limit of Error in Resistance Change from Zero Setting*	Contact Stability	Current Rating, Amperes		Dimensions	Price	Add for Suffix "-B"
4754	11,110	10(1 + 10 + 100 + 1000)	Dial Settings ±(0.05% + 0.005 ohm)	±0.0005 ohm per decade	Highest Decade in Use: 0.1 1 10 100 1000 10,000	Amperes 1.6 0.5 0.11 0.035 0.011 0.003	15⅞″ x 4½″ x 6″ weight approx. 7 lb	$190.00	$175.00
4755	11,111	10(0.1 + 1 + 10 + 100 + 1000)					19¼″ x 4½″ x 6″ weight approx. 9 lb	250.00	200.00
4756	111,110	10(1 + 10 + 100 + 1000 + 10,000)					19¼″ x 4½″ x 6″ weight approx. 9 lb	260.00	200.00
4764	11,111.1	10(0.01 + 0.1 + 1 + 10 + 100 + 1000)	Dial Settings ±(0.05% + 0.005 ohm)	±0.0002 ohm per decade	Equals $\frac{0.5}{\sqrt{R}}$, where R is highest setting of highest decade in use.		10⅛″ x 15⅞″ x 7-1/16″; weight approx. 15 lb	P.O.R.	225.00

**Statements of d-c resistance change assume that boxes have been in regular use, or that dials will be rotated before a box is put in use after a period of idleness. Zero resistance of 4764 does not exceed 0.005 ohm per decade; or for 4754, 4755 and 4756, 0.003 ohm per decade.*

Note: L&N can supply, on special order, resistance boxes for ranges up to 11,111,111 ohms having 8 decades of 10 (1,000,000 + 100,000 + 10,000 + 1000 + 100 + 10 + 1.0 + 0.1).

4631-SERIES SECONDARY-STANDARD A-C RESISTOR

WORKING STANDARDS FOR A-C MEASUREMENTS

Woven construction

Electrostatic shielding

Acrylonitrile-styrene binding posts

Used as working standards for a-c measurements, each of these resistors consists of an insulated manganin wire woven into a resistance webbing, mounted on a ceramic form. Features include electrostatic shielding and acrylonitrile-styrene binding posts. An L&N Report of Calibration is available (suffix "-B").

List Number	D-C Resistance, Ohms	Current Rating, Amperes	Residual Inductance or Capacitance	Limit of Error	Dimensions	Price	Add for Suffix "-B"
4631	1000	0.031	1 μH for 1000-ohm standard; less than 2.5 pF for other standards. These values change less than 5% between 1 and 50 kHz	±0.05% in d-c resistance. Change of resistance with frequency is less than 0.01% for frequencies up to 50 kHz	3¾ x 5½" x 3¾" weight 1¼ lbs	$55.00	$20.00
4632	2000	0.022				55.00	
4633	3000	0.018				55.00	
4634	4000	0.016				55.00	
4640	10,000	0.010				60.00	
4642	20,000	0.007				60.00	

High-Value Resistance Standards (Fixed)

4233-P-□ * WYE-DELTA HIGH-RESISTANCE STANDARD

IMPORTANT
TIGHTEN ALL KNURLED
BEFORE REMOV
STANDARD FROM

FOR CHECKING 4233-A11 BRIDGE

This high-resistance standard is used for checking the 4233-A11 Wide-Range Resistance Bridge at nominal resistances of 10^8 to 10^{15} ohms (10^{16} available on special order). A shield can encloses the resistors, and banana-type receptacle connectors at one end of the standard are arranged to mate with a special connector assembly in the bridge.

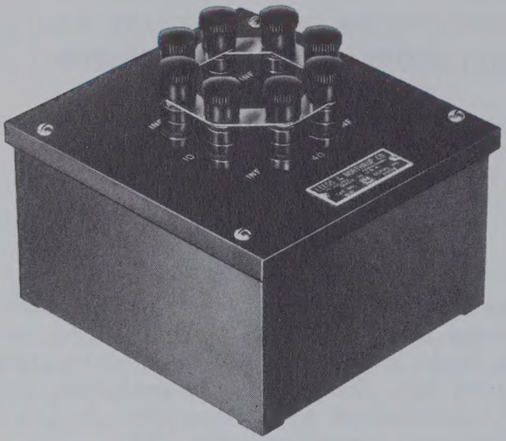
The Wye arrangement of three resistors in the standard becomes effective as a Delta configuration in the bridge circuit. One side of the Delta will be the "X" or check value, one side will shunt the rheostat arm of the bridge, and the third side will act as a high resistance shunt across the power supply. The unique design of this standard eliminates all errors due to leakage.

The 4233-P1 Adapter Kit is available for connecting the Standard to the Wide-Range Resistance Bridge for individual check of resistors which make up the standard.

Complete information and prices on request.

**Number in suffix is exponent of 10 to give nominal value.*

4247 TENTH-MEGOHM STANDARD



A FOUR-SECTION HIGH-RESISTANCE STANDARD

Ring-mounted terminals

The 4247 Resistance Standard is a tenth-megohm high-resistance standard subdivided into four sections. The terminals of the sections are ring-mounted and are connected to binding posts on insulating pillars on the top plate. Links are used for connections between posts.

4249 1-MEGOHM RESISTANCE AND CONDUCTANCE STANDARD

A HIGH-PRECISION STANDARD FOR RESEARCH OR PRODUCTION

Flexible—sections can be grouped in series, parallel and series-parallel

Thermometer wells for internal temperature checks

Thermal shielding

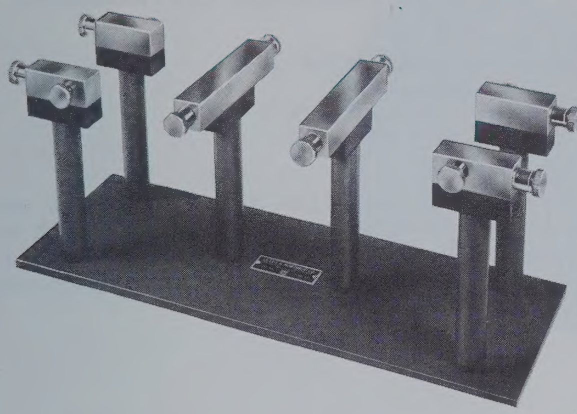
May be used as voltage divider, ratio arms, etc.

Knife-blade switches

The 4249 Megohm Resistance and Conductance Standard is designed for research and production use as a high-precision standard. Unusual flexibility of operation is provided by dividing this standard into ten 100,000-ohm sections which can be grouped in series, parallel and series-parallel arrangements. These combinations are easily obtained by knife-blade switches mounted on the panel. Diagram and connections are engraved on the panel to facilitate setups. This standard may be used as a voltage divider, as bridge ratio arms, etc. Features include a thermally-lagged case to reduce internal temperature variations, and thermometer wells in the panel for checking internal temperatures. An L&N Report of Calibration is available (suffix "-B").

List Number	Resistance, Ohms	Decade Steps	Current Rating, Amperes	Limit of Error	Dimensions	Price	Add for Suffix "-B"
4249	1,000,000 subdivided 10 X 100,000	Knife switches provide: (1 to 10) X 10,000 ohms (1 to 10) X 100,000 ohms (1 to 10) X 1 micromho (1 to 10) X 10 micromhos	2 mA per 100,000-ohm section	For megohm, ±0.02% at 25 C and less than 50% relative humidity Sections are equal within ± 0.01%	12″ x 11″ x 7″ weight 8¾ lb	$1299.00	$140.00
4247	100,000	Subdivided: 10,000 + 20,000 + 30,000 + 40,000 ohms	3 mA	±0.1%	5⅞″ x 6⅛″ x 4⅞″ weight 3 lb	111.00	35.00

ACCESSORIES FOR PRIMARY RESISTANCE STANDARDS



4001 NBS-TYPE MERCURY STAND

Manufactured in accordance with NBS design

Amalgamated top surfaces of solid-copper blocks present extremely low contact resistances

Flat contact surfaces easy to clean and amalgamate

Insulation resistances better than 10 terohms

Provides quick, low-resistance series and/or parallel connections of NBS-type resistance standards. Accommodates up to five standards in series, two in parallel, or series-parallel combinations. A 128436 link may be used with the stand as a low-resistance switch.

DIMENSIONS—6½″ x 6½″ x 14½″.

PRICE—$245.00.

127287 MERCURY-CUP STAND

For supporting and interconnecting NBS- or Reichsanstalt-Type Standards in ratio, resistance, or voltage-drop measurements. Combines low contact resistance with convenience in precise measurement work. Height adjustable from 5⅝″ to 8⅝″. Screw terminals on both sides. Two stands required to support one standard.

PRICE— $37.00.

128436 AMALGAMATED COPPER SHORTING LINK (MALE)

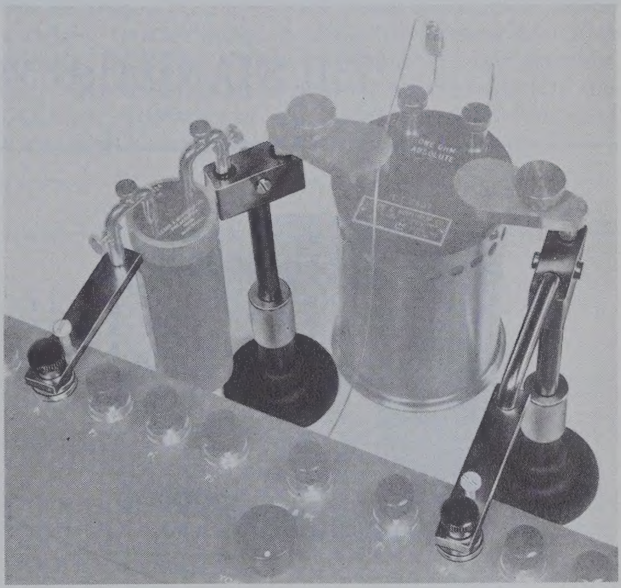
Physically replaces an NBS-Type Standard in making lead compensation, measurement of resistance change, etc. ⅜″ diameter, nickel-plated copper rod, with 3″ span between centers of amalgamated ends.

PRICE—$13.00.

128488 AMALGAMATED BINDING-POST TERMINAL (FEMALE)

For connecting a standard (NBS or Reichsanstalt) to an instrument binding post through a mercury contact surface. Copper bar, 11/16″ x 3½″ x ¼″, with hole in one end for binding post and mercury pool at other end.

PRICE—$11.00.



052845 LABEL (PKG. OF 100)

Useful for noting temperature coefficient data, correction data and certification dates on standards. Adhesive-backed aluminum, 1⅜″ x 2⅛″, it can be attached to standard and immersed in oil indefinitely.

PRICE— $9.40.

113004 ABSORBENT (50-LB. BAG)

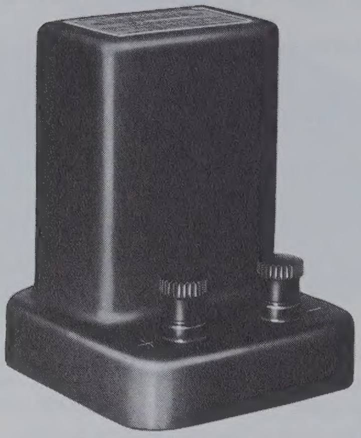
For convenient removal of oil from the standards after they are taken from oil bath. Highly absorbent, the soft particles can be readily brushed from the standard and will not scratch the surface.

PRICE—$11.00.

8401 CONSTANT-TEMPERATURE BATH

See page B-24 for details on a constant-temperature bath with working temperatures of 0 to 100 C.

7308 UNSATURATED STANDARD CELL



FOR USE WITH PRECISION INSTRUMENTS

Copper-lined bakelite case

Low temperature coefficient

The 7308 Eppley Standard Cell is recommended for use with null potentiometers for measurements of high or moderate precision. Mounted in a copper-lined, molded-bakelite case, this cell is supplied with a certificate issued by the Eppley Laboratories.

List Number	EMF at 20 C	Limits of Error	Internal Resistance	Dimensions	Price
7308	Within limits of 1.01884 to 1.01964 Absolute volts	±0.005% of certified value (Eppley certificate)	Not over 500 ohms	4⅛″ x 4″ x 5-3/16″ weight, 2 lb	$50.00

7311 STANDARD VOLTAGE REFERENCE

MODEL NO 121
2846
MADE IN U.S.A.
1
2
3
4
12VDC
GUARD
HEATER
THE EPPLEY LABORATORY INC.
NEWPORT R.I.

STANDARD VOLTAGE REFERENCE PROVIDING LONG LIFE, HIGH STABILITY AND PORTABILITY

Saturated type cells

Portable and shippable

Constant-temperature air bath

High-resolution mercury thermometer

Combining four reliable Eppley saturated standard cells in a dependable temperature-controlled air bath, the 7311 Eppley Standard Voltage Reference provides a compact reference of long life, high stability and portability. It has been selected by L&N as a convenient unit for use with the 7556 Potentiometer, and as a traveling standard for inter-laboratory comparisons. A high-resolution mercury thermometer located in the top panel and extending into the cell chamber permits changes in cell temperature to be easily observed to within 0.005 C. Temperature of the reference is controlled by a mercury thermostat actuating a solid-state switching network. A thermoswitch guard prevents cell damage in the event of failure of the main regulator. A certificate traceable to NBS standards is supplied, stating the cell values to the nearest microvolt. In addition an NBS Calibration Report can be supplied stating cell value to nearest 0.1 μV. The 7311 is housed in a Formica case.

List Number	Input Voltage	Voltage Stability	Power Consumption	Operating Temperature	Thermometer Range	Case	Price
7311	110 V, 60 hertz ac with automatic changeover to 12 V dc standby	1 ppm	Less than 8 watts	28 C, nominal to ±0.01 C; also available at 32 C for higher ambient temperatures	27.8 C to 28.2 C in 0.02 graduations; readable to 0.005 C	12¾″ x 9¾″ x 11″ weight, approx. 30 lb	$850.00

1091 SHIELDED SILVERED-MICA CAPACITANCE STANDARD

LEEDS N NORTHRUP

FOR USE AS ADJUSTABLE HIGH-PRECISION STANDARD OF COMPARISON

L&N type 31 switches

Silvered-mica capacitors

Corrosion-resistant insulated terminals

Provides ultimate in dielectric-to-capacitor plate contact

The 1091 Capacitance Standard provides a capacitance range for use as a standard of comparison in a-c bridge and other measuring circuits, at commercial, audio and higher frequencies. The silvered-mica capacitors employ a unique permanent electrode construction which provides the ultimate in dielectric-to-capacitor plate contact, and thus rigidity of capacitor-plate spacing. L&N Type 31 switches minimize the introduction of undesirable resistance or inductance. An L&N Report of Calibration is available (suffix "-B").

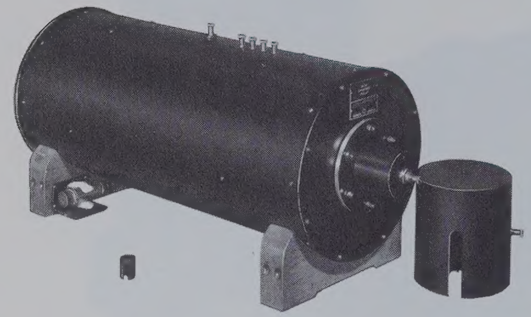
1185-☐ ADJUSTABLE AIR CAPACITOR

FOR ORDINARY CAPACITANCE MEASUREMENTS

This adjustable air capacitor is used for ordinary capacitance measurements. The 1185-A is supplied with calibration data giving capacitance at each five divisions.

List Number	Capacitance	Decade Steps	Limits of Error	Dimensions	Price	Add for Suffix "-B"
1091	1.11 μF max.	10(0.1 + 0.01 + 0.001) μF	Measured from binding posts, at 1000 hertz, capacitance difference between each setting of each dial and its zero setting (other dials on zero) agrees with nominal value of that setting to ±(0.1% + 0.5 pF)	4½″ x 12¾″ x 7¼″ weight, approx. 10 lb	$1000.00	$350.00
1185	Range, 40 to 1100 pF	Scale, 0 to 100 uniform divisions	±5 pF (-B)	6″ x 6″ x 7¼″ weight, approx. 3½ lb	160.00	30.00

1160, - 61 CYLINDRICAL-TYPE FIXED AIR CAPACITOR



FOR MEASUREMENTS AT HIGH VOLTAGE WHEN THE SHIELD IS AT OR NEAR THE POTENTIAL OF THE LOW-VOLTAGE ELECTRODE

Electrostatic shielding

The 1160 and 1161 Fixed Air Capacitors are designed as standards for use with the Schering Bridge where the shield is at or near the potential of the low-voltage electrode. They consist of two concentric cylinders enclosed in a cylindrical case, sealed except for a breather connection through a dryer, and electrostatically shielded and low-voltage electrode guarded.

List Number	Maximum Potential Rating	Nominal Value	Limits of Error	Dimensions	Price
1160	10,000 volts at 60 hertz	100 pF within 2%	Actual capacitance to within ±0.2% of value on nameplate	35¼″ x 12½″ (dia.)	$2800.00
1161	25,000 volts at 60 hertz				3100.00

Inductance Standards

1520-SERIES BROOKS INDUCTOMETERS

ADJUSTABLE, SELF-INDUCTANCE RANGE

Self-inductance scale

Stray magnetic fields produce little error

These adjustable inductors are used for varying the self-inductance of a circuit, or the mutual inductance between two circuits, while keeping the resistance constant. The inductometer has four fixed coils and two movable coils, the latter being mounted in a rotatable disk between the upper and lower fixed plates of the instrument, in which are mounted the fixed coils. As a result of the astatic arrangement of the fixed coils, stray magnetic fields produce little error. The coils are so shaped that the self-inductance scale is nearly linear over a range of about 170°.

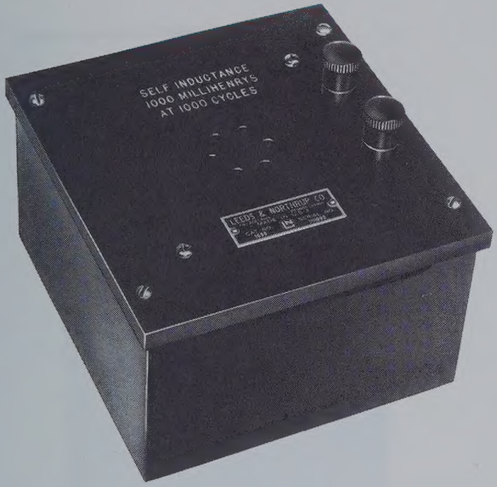
Inductometers used in networks measuring the phase angle of transformers, etc., require special direct-reading scales calibrated in the quantity measured. When special calibration is required, complete circuit constants for the scale computation must be specified.

List Number	Inductance, Millihenrys	Continuous Current Capacity, Amperes	Limits of Error at Frequency of 1000 Hertz	Approximate Time Constant (L/R)	Dimensions	Price
1520-A	1.5 to 12	1.0	±0.3%*	2×10^{-3}	10⅜″ x 10⅜″ x 3¾″ weight approx. 11 lb	$800.00
1520-B	12 to 100	0.35	±0.3%*	2×10^{-3}		800.00
1520-C	100 to 800	0.1	±0.3%**	2×10^{-3}		800.00
1520-D	800 to 6000	0.03	±0.9%***	2×10^{-3}		800.00
1520-X	As Specified	—	—	—		P.O.R.

**Limit of error is per cent of maximum inductance.* ***Per cent of maximum inductance at 1000 hertz; correction data is supplied for 60 hertz.*

****Per cent of maximum Inductance at 60 hertz only.*

1530-SERIES STANDARDS OF SELF-INDUCTANCE



FIXED INDUCTOR

Practically immune to stray-field errors at frequencies up to 1000 hertz

Cause no objectionable external fields

Show no appreciable increase in resistance

As standards of self-inductance, these inductors are used in a-c bridge measurements at low frequencies. The fixed inductors are toroidal coils, mounted on bakelite plates and enclosed in molded-bakelite, ventilated cases. At frequencies up to 1000 hertz, these inductors are practically immune to stray-field errors, cause no objectionable external fields and show no appreciable increase in resistance. An L&N Report of Calibration is available (suffix "-B").

1540 STANDARD OF MUTUAL INDUCTANCE

MUTUAL INDUCTANCE
50 MILLIHENRYS
AT 60 CYCLES
LEEDS & NORTHRUP CO.

FIXED INDUCTOR

Primary and secondary windings have separate binding posts

This inductor is principally used as a standard of mutual inductance for the calibration of fluxmeters. It is also used in low-frequency a-c bridge measurements. The construction of the 1540 is similar to that of the 1530 series. The primary and secondary windings of the toroidal coils have separate binding posts.

List Number	Inductance, Millihenrys	Continuous Current Capacity, Amperes	Limits of Error at Frequency of 1000 Hertz	Approximate Time Constant (L/R)	Dimensions	Price	Add for Suffix "-B"
1530	1	1	±1%	1×10^{-3}	5⅞" x 6⅞" x 4⅝" weight approx. 4 lb	$110.00	$40.00
1531	10	0.5	±0.2%	1×10^{-3}		120.00	40.00
1532	100	0.15	±0.2%	1×10^{-3}		160.00	40.00
1533	1000	0.05	±0.2%	1×10^{-3}		250.00	50.00
1540	50	0.15	±0.5%	5×10^{-4}	5⅞" x 6⅞" x 4⅝" weight approx. 4 lb	165.00	60.00

8411 FIXED TEMPERATURE STANDARD

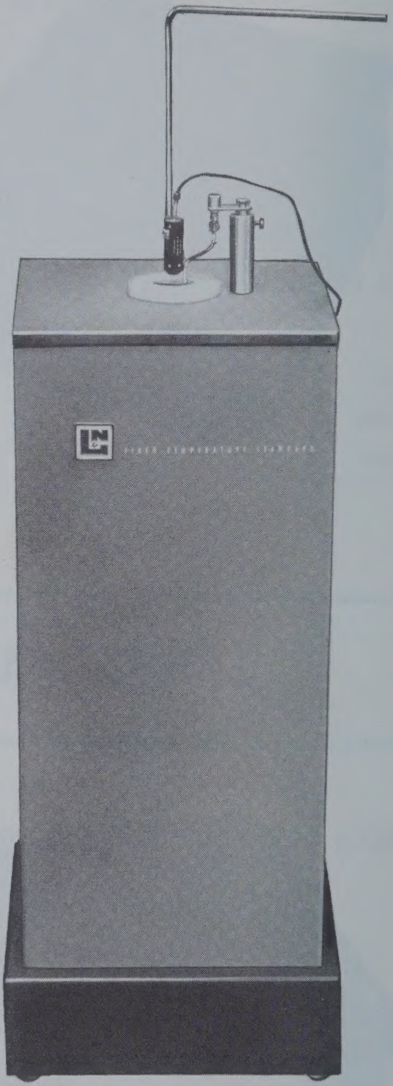
PROVIDES PRECISE CALIBRATION POINT FOR PLATINUM RESISTANCE THERMOMETERS AT FREEZING POINTS OF PURE METALS

Interchangeable cells and equalizing blocks

18″ immersion depth (45.7 cm)

Long-duration temperature plateaus

Simple control system



The 8411 provides a known, fixed reference temperature for calibration of resistance thermometers or thermocouples. The fixed temperature point provided by this equipment is the freezing point of a pure metal. The unit consists of a vertical electric furnace, a temperature-equalizing block and a cell which includes a graphite crucible containing a pure metal sample. Cells and equalizing blocks are replaceable and interchangeable, permitting a single furnace to provide any of the available fixed temperature points. The unit can be ordered by choosing one complete standard and additional cells as desired. You can select from seven metals as shown in the chart below. Metal samples are selected with a purity of better than 99.999% to assure absolutely uniform and precise temperatures.

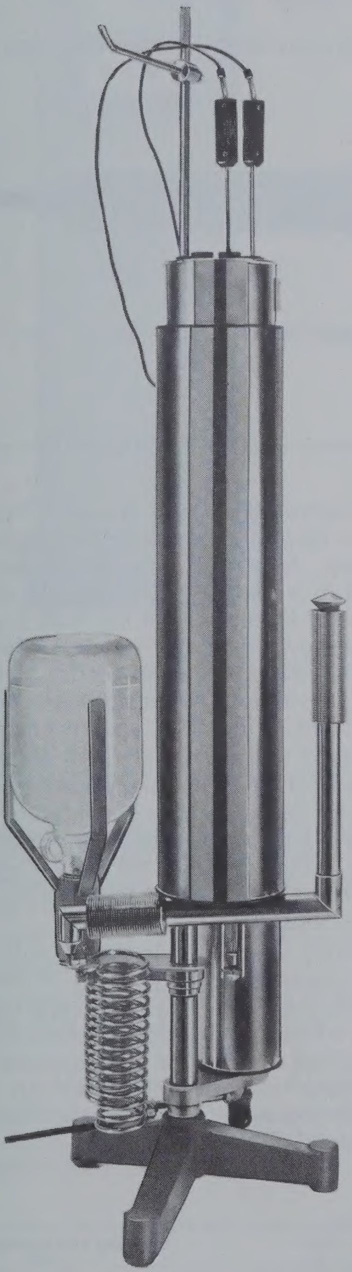
In operation, when the metal sample in the cell reaches its freezing point, the temperature remains constant for an extended period of time, permitting numerous calibrations and tests at this temperature "plateau". The cell is designed to permit the element under test to be immersed to a depth of 18 inches, providing maximum support for the glass tubes of platinum resistance thermometers and also assuring adequate heat retention at the thermometer.

The furnace is housed in an attractive square jacket, topped with a stainless steel cover and work surface located at a convenient 42″ above the floor. Control of the furnace is accomplished by a Powerstat and contactor, which can be either manually operated or combined with recording equipment for automatic operation. The 8411 can be readily converted for interchangeable use as a 9009 Thermocouple Checking Furnace.

Metal	Freezing Points		Complete Temperature Standard	Price	Freezing-Point Cell only	Price	Cell Enclosure	Equalizing Block
	C	F						
Indium	156.61	313.89	8411-IN	$2790.00	8411-IN-C	$985.00	130053 Pyrex $225.00	127543 Copper $435.00
Tin	231.91	449.4	8411-SN	2390.00	8411-SN-C	585.00		
Cadmium	321.03	609.8	8411-CD	2220.00	8411-CD-C	415.00		
Lead	327.3	621.1	8411-PB	2220.00	8411-PB-C	415.00		
Zinc	419.505	787.1	8411-ZN	2220.00	8411-ZN-C	395.00		
Antimony	630.5	1166.9	8411-SB	2535.00	8411-SB-C	685.00	130055 Vycor $350.00	127604 Aluminum-Bronze $480.00
Aluminum	660.1	1220.2	8411-AL	2525.00	8411-AL-C	675.00		

To convert an 8411 Fixed Temperature Standard to a 9009 Thermocouple Checking Furnace add the appropriate 127 ☐☐☐ Equalizing Block (page B-22) and a 402145 Lid Brick (Price $32.50).

8410 STEAM-POINT APPARATUS



PROVIDES FOR PRECISE COMPARISON OF PLATINUM RESISTANCE THERMOMETERS AT THE STEAM POINT

Temperature uniformity assured

Accommodates eight thermometers

One integral assembly for convenient relocation

The 8410 apparatus is designed to produce the steam-point temperature of distilled water at ambient atmospheric pressure. It is used to calibrate platinum resistance thermometers by comparison with a reference thermometer which has been certified by the National Bureau of Standards. It can also be used to ascertain a temperature point to enable calculations of the Fundamental Coefficient and the Callendar and Van Dusen Constants.

The apparatus provides temperature uniformity at the steam point of ±0.001 C and can accommodate eight platinum resistance thermometers.

Constructed primarily of nickel-plated brass, the 8410 consists of one integral assembly which can be conveniently relocated as required. The apparatus is a boiler-type assembly consisting of a boiler, a temperature chamber with an internal arrangement of radiating shields and baffle, a bottle feeder, finned condensers, an atmospheric vent and a loading fixture. The electrical circuit consists of an immersion-type heater which mounts in the bottom of the boiler assembly.

SPECIFICATIONS

OPERATING TEMPERATURE—100 C at an ambient pressure of one standard atmosphere (760 mm Hg).

TEMPERATURE UNIFORMITY—±0.001 C.

POWER REQUIREMENT—120 volts, 50-60 Hz, 300 watts.

WARMUP TIME—Approximately four hours.

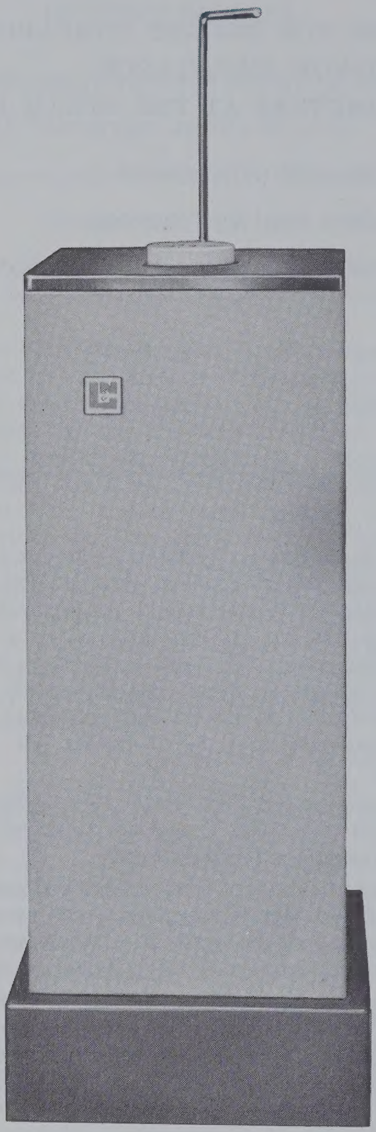
CHARGE CAPACITY—One gallon of distilled water.

OPERATE TIME FOR SINGLE CHARGE—Approximately five days; recharging can be accomplished while the apparatus is in use, with no interruption in operation.

DIMENSIONS—20″ diameter floor space x 45″ high to top of loading fixture; weight, approx. 90 lb uncharged.

PRICE– $3600.00.

9009 CALIBRATING FURNACE

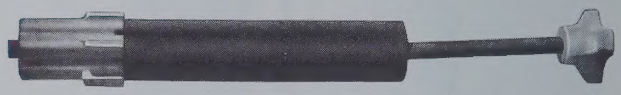


FOR PRECISE CALIBRATION OF THERMOCOUPLES TO 2000 F

Temperature uniformity

Completely factory-assembled

Gold temperature-limit fuse for overheat protection



The 9009 Calibrating Furnace is used with an equalizing block of the desired temperature range, and a checking thermocouple, for the precise comparison of thermocouples up to a maximum temperature of 2000 F. The furnace heater is rated at 3.6 kW, and a gold fuse and contactor is provided for overheat protection. Power supply is 115 or 230 volts, 50/60 hertz, single-phase, as specified. The outside dimensions are a 16¼″ square jacket mounted on an 18¼″ square base by 42″ high. The work space is 4″ in diameter and 30″ deep.

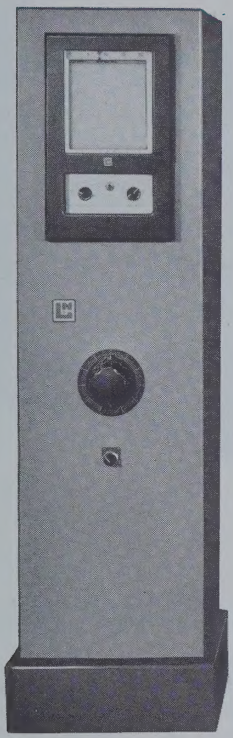
A choice of three equalizing blocks is provided, depending upon the maximum temperature desired. The blocks have a pedestal and ceramic centering insulator, and are 3″ in diameter and 14″ long. They have seven immersion holes each 9/16″ in diameter by 12″ deep, one at the center and six on a 1″ radius.

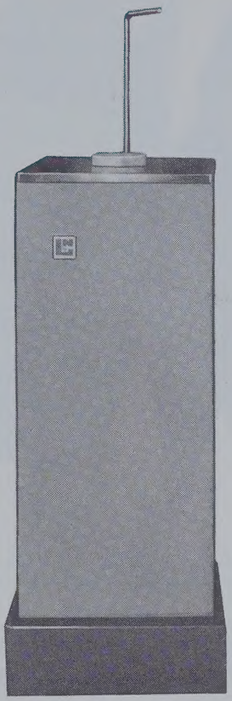
The checking thermocouple for use with any of these equalizing blocks is constructed of 24 AWG platinum-10% rhodium, platinum wires with single-hole insulators, mounted in a Fyrestan® protecting tube with ⅜″ OD. The head is modified so extended thermocouple wires enable the reference junction to be placed in an ice-bath. The checking thermocouple is available with an L&N Report of Calibration.

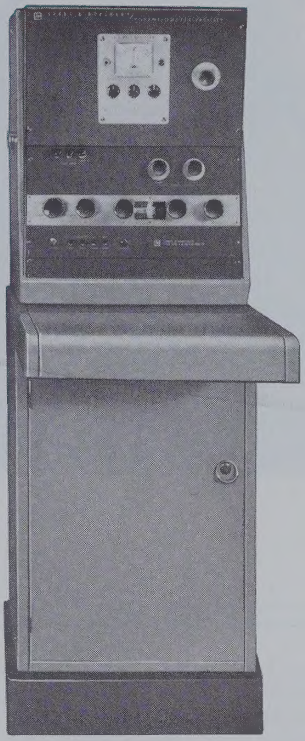
	Calibrating Furnace	Equalizing Block			Checking Thermocouple*	
		Copper Max., 800 F	Aluminum Bronze Alloy Max., 1850 F	Inconel Max., 2000 F	With L&N Report of Calibration	Without L&N Report of Calibration
List No.	9009-□-□	127379	127383	127382	8710-B-K2025-24-□	8710-K2025-24-□
Price	See Table Page B-23	$250.00	$395.00	$445.00	$215.00*	$120.00*

**Add required length of wire extension, in inches, as suffix to List No. @ $2.00 per inch.*

THERMOCOUPLE CALIBRATION ASSEMBLY







A compact, convenient, ready-to-use thermocouple calibration assembly for both plant and laboratory applications consists of a 7554-A11-C1 Type K-4 Potentiometer Facility, a 9009 Thermocouple Calibrating Furnace, plus a choice of one of four temperature controls for the Calibrating Furnace.

Selection is specified by adding one of the following suffixes as the first suffix to the furnace List Number 9009-☐-☐:

-A1 or -A2 . . . Manual control with Powerstat. -A1 is mounted by customer; -A2 is factory-mounted and wired, within a steel panel enclosure. Dimensions: 18¼″ square base, 16¼″ square body, 42″ high.

-A3 or -A4 . . . Steel enclosed control panel with all accessories factory-mounted and wired. Dimensions: 18¼″ square base, 16¼″ square body, 62″ high. -A3 uses an Electromax® 2-position Signaling Controller; -A4 uses a Speedomax H Model S Indicating and Recording Controller for 2-action D.A.T. Control (10876-type).

For the second suffix, specify power requirements of 115 V or 230 V, e.g. 9009-☐-115 or 9009-☐-230, to complete the List Number.

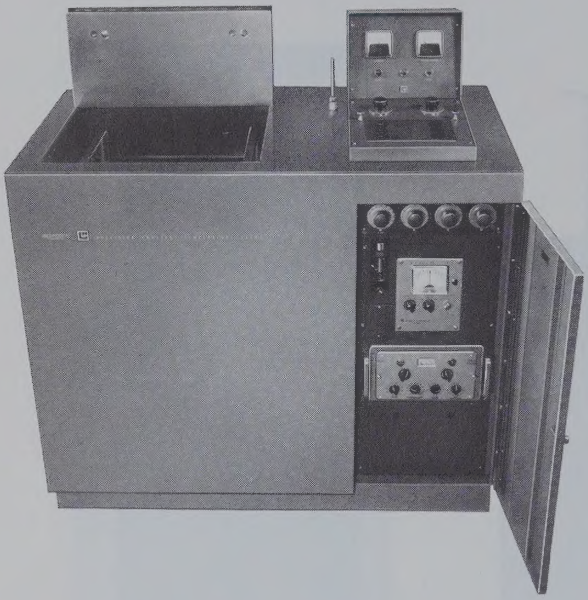
-D1 . . . Reference Junction Ice Bath available as an option, provides for 20 reference junctions (10 thermocouples) in a single unit. Includes hardware for mounting unit on the side of the 9009 Calibrating Furnace.

Item	9009-A1-115 9009-A1-230	9009-A2-115 9009-A2-230	9009-A3-115 9009-A3-230	9009-A4-115 9009-A4-230
Thermocouple Calibrating Furnace	$1260.00*	$1086.00*	$1153.00	$1153.00
Temperature Control Panel	**	740.00	808.00	815.00

**Optional Item: For thermocouple assembly located in base of furnace complete with mounting clamp and 25 ft. of extension wire, add $67.00.*

***Price of 9009-A1-☐ includes Powerstat and contactor. For the other assemblies these items are included in the price of the temperature control panels.*

8401 PRECISION CONSTANT-TEMPERATURE BATH



HIGHEST-PRECISION TEMPERATURE ENVIRONMENT FOR LABORATORY SERVICE

Unique temperature-control system

Cooling coils provided for precise control at temperature close to or below ambient

Large, unhindered work area

Auxiliary heater for quick startup or high-temperature operation

The 8401 Constant-Temperature Bath is ideal for precise comparison of saturated standard cells, resistance standards, electrolytic-conductivity cells and other laboratory devices that require an extremely stable and uniform temperature environment. Other applications include: calibration of fever thermometers; calibration of contact resistance thermometers, thermistors and other temperature sensitive resistive devices; measuring and controlling temperature of small electrical components, such as silicon chips, integrated circuits, etc.; and providing an environment for living cells.

The bath features a large, unhindered work area measuring 18″ square and 9″ deep. Up to sixty racked standard cells can be accommodated at one time. Working temperatures range from 0 to 100 C. Consistency and uniformity are within ±0.001 degree C without attention for at least 24 hours in the range of 15 to 60 C, under typical laboratory environments (no rapid fluctuations in ambient temperature), and within ±0.003 degree C in the ranges of 0 to 15 C and 60 to 100 C under the same conditions.

A metal cabinet houses the oil-flow (can also be used with water) and temperature control system. Cooling coils surrounding the metal tank permit precise control at temperatures close to or below ambient. Tank capacity is 36 gallons. Power requirements are 120 volts, 60 hertz, with maximum current of 15 amperes. Overall cabinet dimensions are 43″ x 51″ x 26″.

PRICE—$7,200.00. For standard cell applications, add for each cell bank (regardless of number of cells per bank)—$75.00.

When ordering the 8401-A □□□-□-□, 8401-B-□-□, or 8401-C-□-□ Bath Assembly, please specify the following on all orders:

Basic List Number	First Element		Second Element		Third Element	
	Add Suffix	For Application	Add Suffix	For Power Supply	Add Suffix	For Intermediate Overheat Control
8401	A□□□*	For Standard Cells	-6	For 60 Hertz	-0	Control not supplied
	-B	For Resistance Standards				
	-C	For Conductivity Cells and General Purpose Use	-5	For 50 Hertz	-1	Control supplied

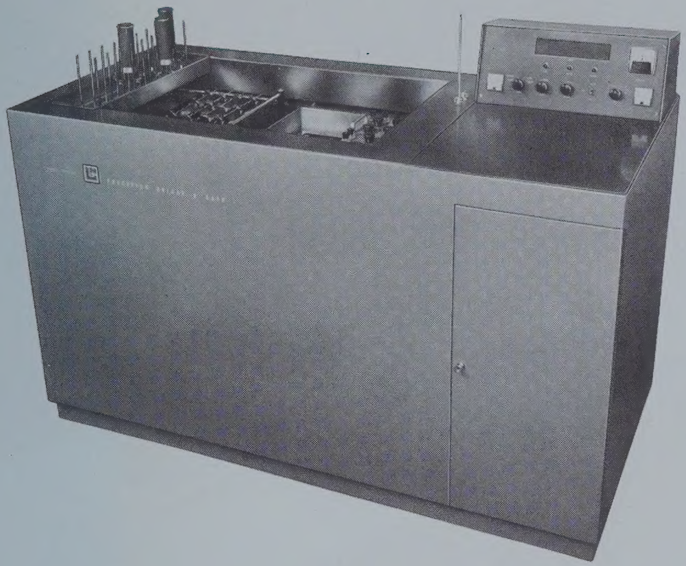
*FOR STANDARD CELLS THE COMPLETE SUFFIX FOR THE FIRST ELEMENT CONSISTS OF THREE FIGURES:

FIRST FIGURE (A1, A2, etc. up to A5) defines type of cell bank: A1 □ □, Eppley 3-cell; A2 □ □, Eppley 4-cell; A3 □ □, Eppley 5-cell; A4 □ □, Eppley 6-cell; and A5 □ □, Weston 4-cell;

SECOND FIGURE is a numeral from 1 to 10 specifying the number of cell banks to be accommodated (maximum of 10 banks regardless of number of cells per bank);

THIRD FIGURE is a letter P, for leads to binding posts, or R, for leads to rotary switches.

8403 PRECISION BRIDGE & BATH



FOR INTERCOMPARISON OF PRIME RESISTANCE STANDARDS & COMPARISONS OF SECONDARY OR WORKING STANDARDS WITH PRIME STANDARDS

Combines constant-temperature bath and Kelvin-Wheatstone ratio set

Rear-projection-type digital readout

Provision for conditioning resistors before measuring

This precision resistance-standard measuring facility, combining the features of a constant-temperature oil bath and Kelvin-Wheatstone Ratio Set, was designed to facilitate the calibration of high-accuracy d-c resistance standards. The ratio-set resistors and terminals, as well as the resistors to be calibrated, are immersed in the bath oil to minimize temperature fluctuations and provide an ideal calibration environment. Separate areas are provided for conditioning, measuring and draining of resistors. Provisions are made for either two-terminal Wheatstone-bridge measurements or four-terminal Kelvin bridge measurements, and for connecting series, parallel, and series/parallel combinations for checking intermediate-value standards. Connections between the resistors to be measured and the ratio set are made by mercury contact, thus eliminating the need for interconnecting wires. Binding posts are provided at all ratio-set terminals which allow connections to resistors in a remote bath for temperature-coefficient determinations.

SPECIFICATIONS

BATH

OPERATING RANGE—20 to 30 C.

CONSTANCY AND UNIFORMITY—±0.01 C.

SETABILITY—Better than 0.001 C.

TEMPERATURE CONTROL—Consists of a 3-dial (2 switches and slidewire) set-point unit, 9834-2-S detector, 10877-S C.A.T. control unit and a silicon-controlled rectifier. One-half division on the set-point slidewire dial equals 0.01 ohm which corresponds to a change of approximately 0.001 C in bath temperature.

COOLING—When the bath is operated near or below ambient temperature, auxiliary cooling is required. Tap water is usually satisfactory for bath temperatures down to 20 C in a 25 C ambient. Refrigerated coolant from an auxiliary cooling unit may be desirable.

POWER REQUIREMENT—120 V, 60 Hz, 650 W.

CABINET—All-metal cabinet with stainless-steel tank and work surface; capacity approximately 50 gallons; 65⅞″ (w) x 31⅜″ (d) x 55½″ (h) overall.

BRIDGE

RANGE—−500 to +600 ppm (with fifth dial option, range is −5000 to +6000 ppm).

RESOLUTION—0.1 ppm.

RATIOS—100:100, 100:50, 100:20, 100:10.

LIMIT OF ERROR—±1 ppm on 100:100 ratio; ±20 ppm on other ratios without corrections.

LEAD COMPENSATION—Built-in; compensates for effect of lead resistance on bridge ratios.

READOUT—Rear-projection-type digital display.

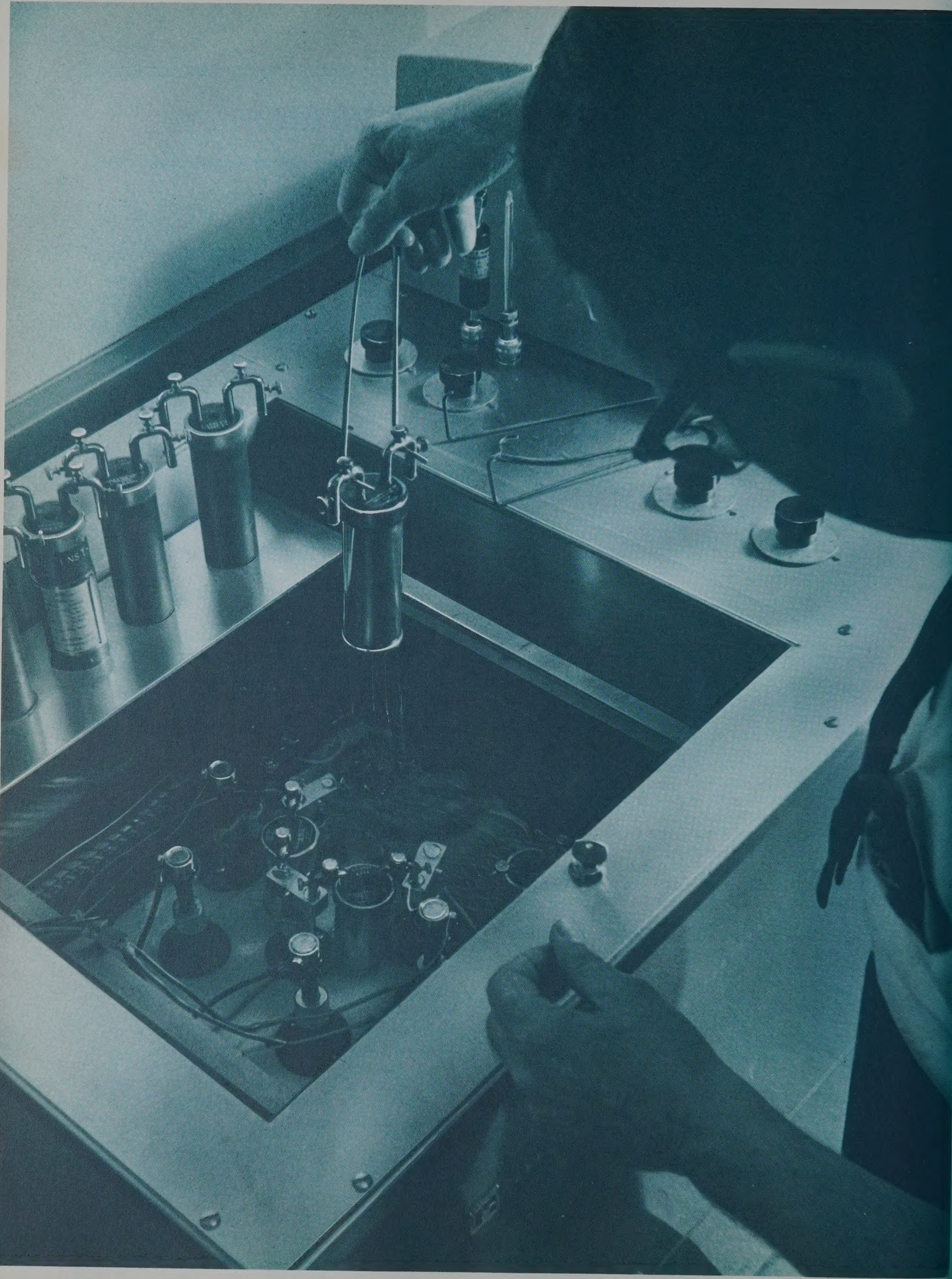
DETECTOR—Built-in 9838-1 Nanovolt Detector.

POWER SUPPLY—Current: Ni-Cd battery with built-in charging circuit. Two ranges, 0-2 amperes and 0-20 amperes. Binding posts provided for external supply. Voltage: Switch-selected 1.5, 3, 7.5, 15, 22.5 and 45-volt battery supply.

PRICE—On Request.

RECOMMENDED ACCESSORIES

(11) 4030-B, 100-ohm NBS resistance standards required for 1 ppm calibration of ratios other than 100:100.



C

COMPARATORS

Introduction C-1
Potential Dividers and Ratio Sets C-7
Voltage Dividers C-13
Slidewires C-16
Specialized Comparators and Test Sets C-18

EEDS & NORTHRUP

COMPARATORS AND RATIO DEVICES

Leeds & Northrup manufactures a variety of comparison devices for applications such as the calibration of instruments and the intercomparison of standards and thermocouples in standardizing and calibration laboratories. This group of instruments includes ratio sets, potential dividers, voltage dividers, and comparators for standard cells and thermocouples, as well as ratio boxes and slidewires which can be used in the construction of assemblies for a variety of general and specialized measurements. In addition, L&N can provide a-c current and potential test sets for the comparison of instrument transformers with a certified standard. Each L&N comparison device is a well-built, thoroughly-tested instrument which reliably provides a degree of precision within its stated limits of error.

FACTORS IN USE OF COMPARISON DEVICES

Comparison devices are useful when two electrical quantities must be compared. Differences are read out either directly or in the form of ratios from which differences can be calculated. Sometimes the difference or deviation alone is the information desired. Where one of the elements is a standard of known value, the difference can be used to determine the unknown value.

Comparison devices are most useful where the difference is only a small part of the total value of the unknown. In effect, considerably more meaningful resolution can often be provided by a deviation measurement than where the total value is read out. A wide range of values can be determined on this basis if suitable standards are available.

A comparison device for *difference* use, such as a thermocouple or standard-cell comparator, has an adjustable element which establishes a null balance with the difference between two thermocouples or two cells, and permits readout. For *ratio* measurements, two elements are involved, at least one of which is adjustable. In its simplest form, it may be a slidewire with a movable contact to provide a known proportion between the contact and each end of the slidewire.

Comparison devices may utilize a direct-ratio, direct-substitution or double-substitution approach to determine the value of the unknown to be measured.

Direct Ratio
X on left S on right
Read

Direct Substitution
dummy on left S on right
dummy on left X on right (substitute X for S)
Subtract

The direct substitution method reduces lead resistance and ratio error.

Double Substitution
X on left S on right
S on left X on right (interchange X and S for second reading)
Subtract and divide by 2

The double-substitution method reduces lead-resistance and ratio error but is generally restricted to 1:1 ratios.

APPLICATION OF COMPARISON DEVICES

Comparison devices can be used to compare standard cells, thermocouples, and resistors—the latter both individually and within bridges or potentiometers. For example, two thermocouples (a standard and an unknown) can be compared to establish corrections, two standard cells can be checked for difference, resistance standards can be compared to each other or to equivalent elements of a voltage divider, potentiometer or bridge. It is evident, therefore, that these devices are extremely useful as calibrating tools.

Brief descriptions follow on the application of specific comparison devices for measuring resistances, dividing voltages, calibrating standard cells and thermocouples and testing transformers. Detailed descriptions, specifications and illustrations of all L&N comparators are provided on the following pages.

MEASURING RESISTORS WITH RATIO SETS

RESISTORS WITHIN NOMINAL RATIOS OF 1:1 — When greater accuracy is required in the measurement of precision resistors than is available with conventional Wheatstone or Kelvin bridges, a Direct-Reading Ratio Set (DRRS) or Kelvin Ratio Set can be used. The Direct-Reading Ratio Set, described in NBS Circular 470, consists of only the ratio arms of a Wheatstone bridge (Figure 1). These ratio arms contain one fixed arm and one adjustable arm, and limit the available ratio range to approximately ±½% when comparing an unknown resistor to a standard. Because the standard is not incorporated within the instrument and the ratio range is narrow, it is possible to compare a wide range of unknowns to their equivalent standards, within a limit of error of ±1ppm. X and S can be interchanged for a second measurement and the results averaged. This double-substitution measurement permits achieving the highest accuracy. If lead resistance is significant, a series of measurements must be made to eliminate the effect of this resistance. The 4398 Double-Ratio Set is a multi-function instrument which can be used as a Direct-Reading Ratio Set.

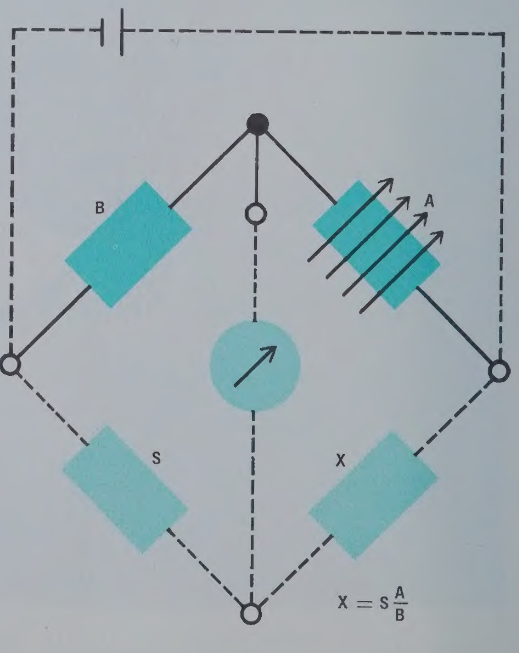
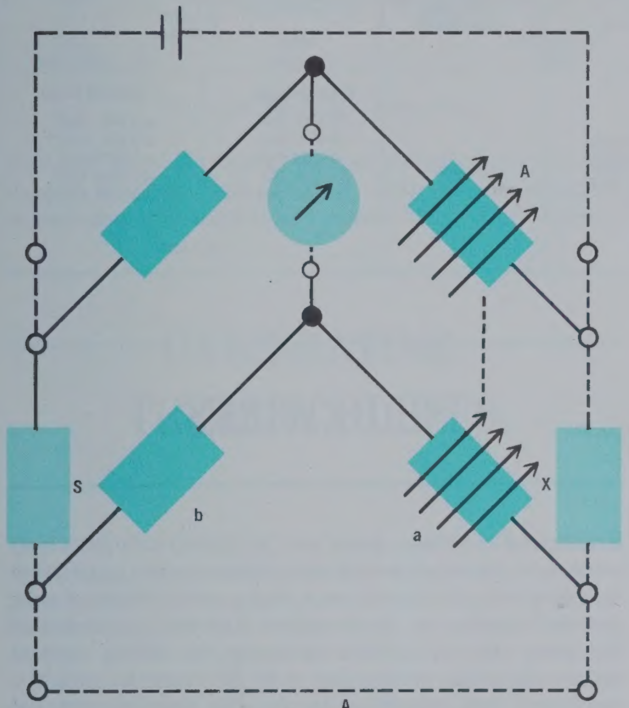


FIG. 1 Direct Reading Ratio Set.

RESISTORS WITHIN NOMINAL RATIOS OF 10:1—A Kelvin Ratio Set (Figure 2) eliminates the need for multiple balances when lead resistance is significant, and is designed to be direct reading in terms of percent or ppm.

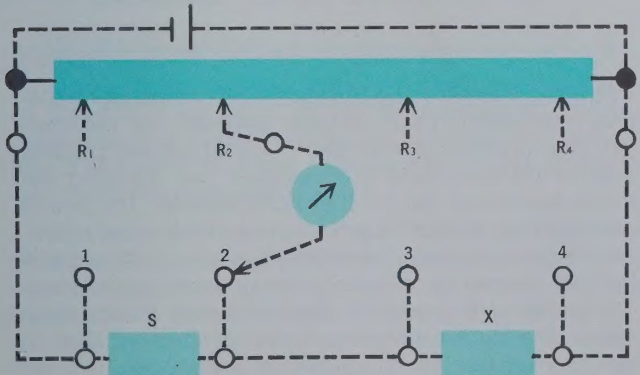
The 4394 Kelvin-Wheatstone Ratio Set also has provision for measuring a value of X that is 1/10 (or 10 times) the value of S, providing the ratio of 1/10 is within approximately ±½%. A double substitution cannot be made in this situation and the 1-ppm limit of error is obtainable only by using a direct substitution of X for a known standard that has been measured in the X arm, and measuring the difference of the two resistors, or calibrating the ratio set by using the "rotating standard" technique.



$$X = S\frac{A}{B}$$

FIG. 2 Kelvin Ratio Set.

ODD-VALUE RESISTORS—A Universal Ratio Set (URS) is frequently used to measure odd-value resistors in terms of decade-value standards (Figure 3). The 4393 Six-Dial Universal Ratio Set can measure any resistance ratio from 1:1 to 1:10, using all dials of the instrument. When measuring ratios of 1:1 it is capable of achieving a 1-ppm limit of error, while the usual odd-ratio measurement involves a limit of error of ±20 ppm. The Universal Ratio Set is not a direct-reading instrument, particularly when used to measure resistances. When lead resistance is significant, up to four measurements plus a computation are required to obtain a value of X in terms of S.



$$X = \frac{R_4 - R_3}{R_2 - R_1} S$$

FIG. 3 Universal Ratio Set.

The Universal Ratio Set can also be used as a low-impedance voltage divider for the calibration of potentiometers and the comparison of standard cells.

The 4399 Seven-Dial Potential Divider is a seven-dial version of the URS. Although this instrument is identical to a URS in usage and impedance, it was called a potential divider because it is constructed with a shunted Kelvin-Varley circuit instead of dual decades used in the original URS. Another change is the addition of end resistors for greater precision on 10:1 and 1:10 ratios. A complete measurement facility can be built around this Seven-Dial Potential Divider to handle voltage as well as resistance comparisons.

The 4398 Six-Dial Double Ratio Set combines the direct-reading features of the Kelvin Ratio Set with the wide range of the URS for the most accurate and convenient measurement of resistors in terms of decade-value standards. It is a particularly desirable type of ratio set where low, odd-value resistors must also be precisely measured.

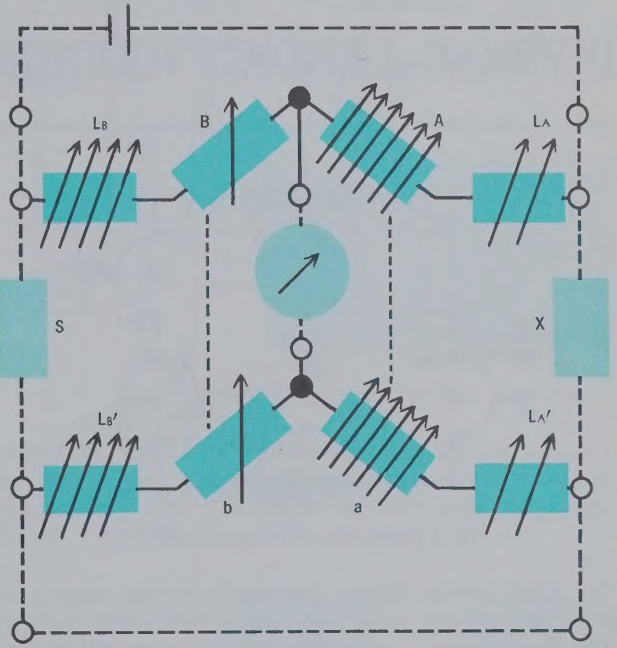


FIG. 4 Six-Dial Double Ratio Set.

This instrument consists of the battery and yoke arms of a Kelvin bridge, as shown in Figure 4. Each of the four arms is adjustable: the "A" and "a" mechanically-coupled ratio arms have six decades adjustable in steps of 0.001 ohm, and the "B" and "b" mechanically-coupled ratio arms consist of a single decade adjustable in 100-ohm steps. Thus by selecting the proper dial settings on the "A" and "B" ratio arms, odd-value resistors can be measured in terms of decade-value standards. A resolution and limit of error of ±1 ppm is possible with this instrument when making 1:1 comparisons using the direct or double-substitution method, providing the standard resistor and test resistor are alike to within ±0.1%. When other ratios are used and correction data is not used, the limit of error of nominal readout is ±20 ppm.

SELECTION GUIDE—L&N Ratio Sets (Resistance Applications)

<table>
<tr><th>Instrument</th><th>Functions</th><th>Range</th><th>Resolution</th><th colspan="2">Achievable Accuracy</th></tr>
<tr><td rowspan="2">4393
Universal
Ratio Set</td><td>Comparison of Odd-Valued Resistors
Comparison of Resistors of Same Nominal Value</td><td rowspan="2">2111.110 ohms
Ratios of approx. 1:1 to 20:1 using six dials</td><td rowspan="2">0.001 ohms</td><td colspan="2">(a) 20 ppm for ratio settings involving one or more steps on the 100 dial above the zero position.
(b) For ratio settings involving changes in dials below 100, the accuracy of reading is within 2 steps on the 0.001 dial.</td></tr>
<tr><td>Comparison of Standard Cells
Calibration of Precision Potentiometers</td><td colspan="2">–</td></tr>
<tr><td rowspan="2">4394
Four-Dial
Kelvin-Wheatstone
Ratio Set</td><td>Comparison of 10:1 Resistors</td><td rowspan="2">99.5000%
to
100.6110%</td><td rowspan="2">1 ppm</td><td colspan="2">± 20 ppm nominal readout (approaches ± 1 ppm with calibration)</td></tr>
<tr><td>Comparison of 1:1 Resistors</td><td colspan="2">± 1 ppm</td></tr>
<tr><td rowspan="2">4398
Six-Dial
Double
Ratio Set</td><td>Comparison of Odd-Valued Resistors
Comparison of 1:1 Resistors</td><td rowspan="2">0.0001 ohm
to
100 K ohms</td><td rowspan="2">1 ppm
("A" arm
–1000 ohms)</td><td colspan="2">± 20 ppm nominal readout
(± 1 ppm with corrections)</td></tr>
<tr><td>Direct-Reading Ratio Set
Resistance Thermometry
Limit Bridge</td><td colspan="2">± 1 ppm
± 30 ppm
–</td></tr>
<tr><td rowspan="2">4399
Seven-Dial
Precision
Potential
Divider</td><td>Universal Ratio Set
(Calibration of Highest-Precision Potentiometers and Primary Resistance Standards)</td><td rowspan="2">2,111.1110 ohms
Ratios of approx. 1:1 to 20:1 using seven dials.</td><td rowspan="2">0.05 ppm</td><td>Dial Changed
100-Unit Dial
10-Unit Dial
1-Unit Dial
0.1-Unit Dial
3 lowest dials</td><td>Limit of Error
±0.002 Unit
±0.001 Unit
±0.0004 Unit
±0.0002 Unit
±0.0001 Unit ea.</td></tr>
<tr><td>Voltage Divider
Direct-Reading Potentiometer</td><td colspan="2">± 1 ppm</td></tr>
</table>

DIVIDING A KNOWN VOLTAGE

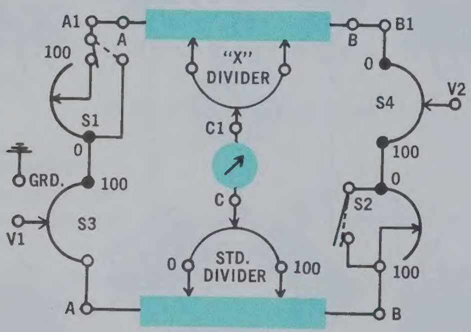


FIG. 5 Calibration of Voltage Divider.

The 4395 Voltage Divider provides a precise means of dividing a known d-c or a-c (up to 1000 hertz) voltage into known parts. The known voltage is applied to the input terminals and the three ratio dials and slidewire are adjusted to obtain the desired fraction of the input voltage at the output voltage terminals.

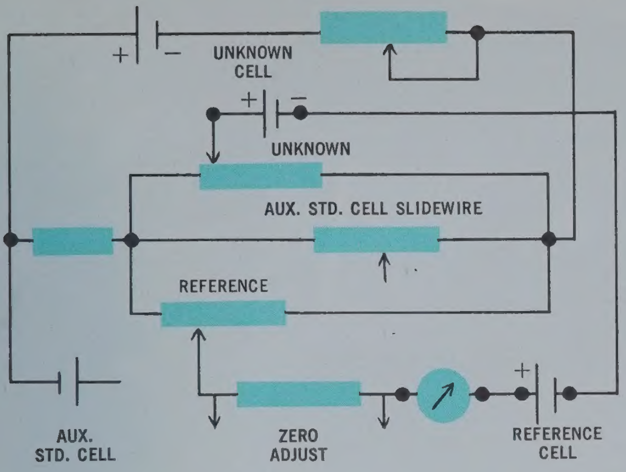
The 4396 Precision Voltage Divider Standard utilizes the basic Kelvin-Varley circuit, with additional circuitry for convenient calibration of precision voltage dividers as shown in Figure 5. This additional circuitry includes slidewires with the necessary range and resolution to balance out the effects of interconnecting leads, and to provide zero offset when the 4396 is paralleled with the voltage divider to be checked. The use of these components permits making a null balance when comparing the 4396 to any setting of the voltage divider being checked. The 4396 itself may be recalibrated by another 4396 or by comparing the settings of each decade to a special set of ten matched, calibrated and temperature-controlled standards.

SLIDEWIRES

A slidewire may be a solid wire stretched straight along a scale, or mounted on the circumference of a graduated disk or drum, or—to secure a higher resistance—a wire wound helically on an insulated mandrel, mounted in the same way as a solid slidewire. A sliding contact makes electrical connection with the wire to vary the resistance in a circuit, or to vary the drop of potential from one end of the wire to the contact when a fixed current is flowing through the wire. L&N provides a selection of slidewires to form the ratio arms of simple bridge circuits.

MEASURING VOLTAGES OF STANDARD CELLS

The 7565 Direct-Reading Standard-Cell Comparator measures the difference in voltage between an unknown cell and a reference standard cell, and permits reading directly the voltage of the unknown cell. Utilizing the lower decades of the Six-Dial Potentiometer, the Standard Cell Comparator is actually two short-range potentiometers in parallel. The elementary circuit diagram of the 7565 Comparator (Figure 6) shows three parallel arms. The center arm is used to standardize the voltage drop across the "unknown" and "reference" arms. Due to the short range of the potentiometers (2300 μV), an unsaturated cell provides more than adequate standardizing accuracy. The "reference" and "known" potentiometers are 10 ohm-per-step Kelvin-Varley voltage



+
–
UNKNOWN CELL
+
–
UNKNOWN
AUX. STD. CELL SLIDEWIRE
REFERENCE
AUX. STD. CELL
ZERO ADJUST
+
REFERENCE CELL

FIG. 6 Standard-Cell Comparator.

dividers, each consisting of four decades. The lowest decade provides steps of 0.1 μV. Thermal compensation is included to make the instrument truly direct-reading.

CALIBRATING THERMOCOUPLES

The 8693-A12-127-☐☐☐ Thermocouple Comparator combines a temperature potentiometer and a zero-center Speedomax recorder to provide a chart record of required thermocouple corrections for each of sixteen thermocouples (more with extra switches) from the standard calibration curve directly in degrees at any temperature maintained by a simple checking furnace. The first range is selected for the major type of thermocouple to be checked; a second range in millivolts provides for other types.

The thermocouples to be calibrated and the reference thermocouple are placed in a checking furnace which is stabilized at the desired checking temperature. The furnace temperature is measured by means of the reference thermocouple and the temperature potentiometer. Here the Speedomax recorder is used as a null detector, with the chart switch set at OFF and the function switch set at MEAS.

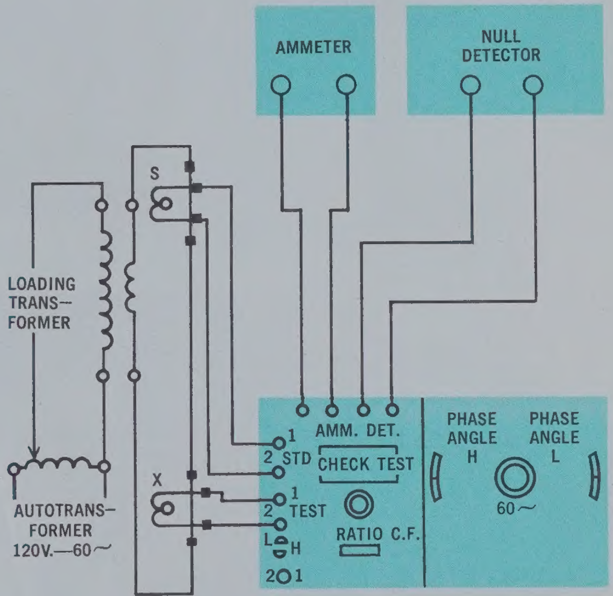
The function switch is then set at OUTPUT, and the recorder span is adjusted by changing potentiometer settings and the span-adjustment knob of the recorder so that the scale range of 10-0-10 corresponds to the desired degree-deviation range; for example, to a deviation of 10 F, 20 F, 30 F etc. (minimum of 150 μV) on each side of the checking temperature.

The chart switch is then turned ON and the function switch to REC and each thermocouple is connected in sequence to the measuring circuit by means of the thermocouple selector switch. The record on the chart will then indicate the required correction data for each thermocouple directly in degrees F or C, at the desired temperatures as established by the furnace. A unique span divider provides high accuracy for short spans when using the wide-range potentiometer for calibration.

SPECIALIZED COMPARISON DEVICES

The 1553 Campbell-Shackleton A-C Ratio Box can serve as the nucleus of a variety of one-to-one bridges for impedance measurements.

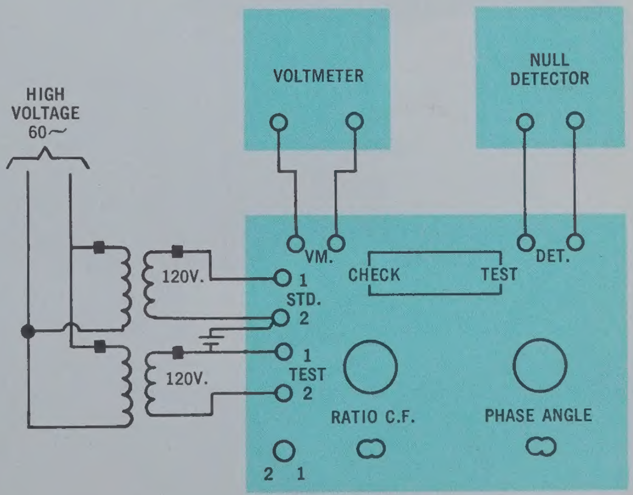
The 7151 Silsbee Current-Transformer Test Set is used for the comparison of 60-hertz instrument current transformers with a certified standard current transformer. A typical test set-up is diagramed in Figure 7.



AMMETER
NULL DETECTOR
S
LOADING TRANS-FORMER
X
AUTOTRANS-FORMER 120V.—60~
1
AMM. DET.
2 STD
CHECK TEST
1
2 TEST
L H
2 1
RATIO C.F.
PHASE ANGLE H
PHASE ANGLE L
60~

FIG. 7 Current-Transformer Test Set.

The 7161 L&N Potential Transformer Test Set is used for the comparison of 60-hertz instrument potential transformers with a certified standard potential transformer (Figure 8).

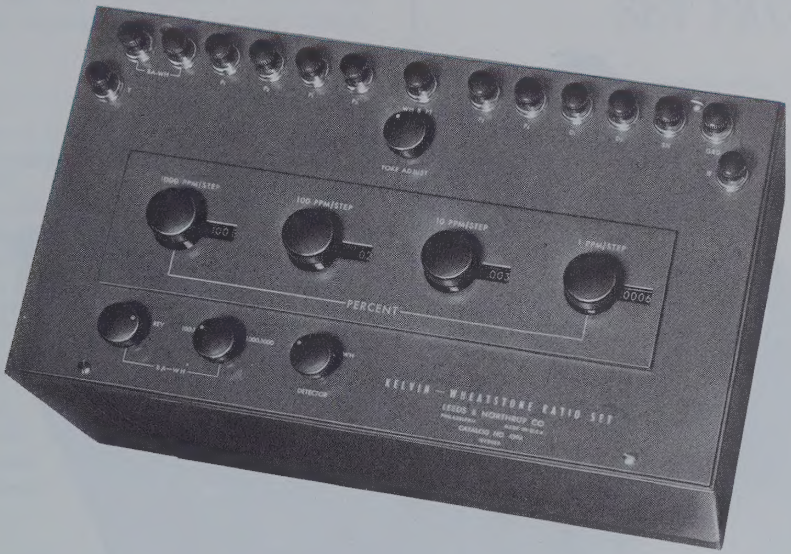


HIGH VOLTAGE 60~
VOLTMETER
NULL DETECTOR
VM.
DET.
120V.
1
STD.
2
CHECK
TEST
1
TEST
2
120V.
RATIO C.F.
PHASE ANGLE
2 1

FIG. 8 Potential Transformer Test Set.

LEEDS & NORTHRUP
D-C NULL DETECTOR
LEEDS & NORTHRUP
DIRECT READING STANDARD CELL COMPARATOR
COARSE

4394 FOUR-DIAL PRECISION KELVIN-WHEATSTONE RATIO SET



HIGH ACCURACY . . . ±1 PPM FOR 1:1 COMPARISONS (APPROACHES ±1 PPM FOR 10:1 COMPARISONS, WITH CORRECTIONS)

L&N type 31 switches

Matched principal resistors housed in thermally-lagged chamber

Electrostatic and thermal shielding

Gold-plated copper binding posts

Additional binding posts for certification, and for use of one ratio arm as adjustable resistance standard

---

The 4394 Ratio Set is a precise ratio device for the intercomparison of high-accuracy d-c resistance standards in standardizing laboratories. It is used primarily for calibration of NBS -type (4020 Series) and Reichsanstalt-type (4221) resistance standards using the 4210 Thomas One-ohm Standard as the reference. Designed for either two-terminal Wheatstone-bridge or four-terminal Kelvin-bridge measurements, this ratio set incorporates many features to provide the ultimate in accuracy: the principal resistors in the ratio arms are carefully matched to have essentially the same temperature coefficient, and are enclosed in an inner thermal-equalizing chamber; Type 31-3 adjustable-arm switches are totally enclosed and have silver-alloy contacts; and the metal top-plate and box provide complete electrostatic shielding. An L&N Report of Calibration is available (add suffix "-B").

SPECIFICATIONS

RANGE—99.5000% to 100.6110%.

SETABILITY—0.0001% (1 ppm).

LIMITS OF ERROR—For 1:1 comparisons by the direct or double substitution methods, limit of error is ±0.0001% (±1 ppm), providing that the standard resistor and resistor under test are alike within 0.1%. For comparisons using the 10:1 ratio, limit of error approaches ±0.0001%.

L&N REPORT OF CALIBRATION—Changes of less than 1000 ppm are correct within 0.1 ppm; larger changes are correct within 0.5 ppm.

RATIO ARMS—Double set of ratio arms for Kelvin-bridge measurements; one set used for Wheatstone-bridge measurements. All principal resistors are hermetically sealed and have matched temperature coefficients. *Fixed Arms:* 1000 ohms, consisting of ten 100-ohm resistors. A 100-ohm tap is provided for ratios of 10:1. *Adjustable Arms:* Four Waidner-Wolff resistance decades provide adjustments between 995.000 ohms and 1006.110 ohms in steps of 0.001 ohm. First dial: 99.5% to 100.5%. Other dials marked .00 to .10, .000 to .010, and .0000 to .0010.

YOKE ADJUSTMENT—Three-turn slidewire in apex of yoke ratio arms permits exact adjustment of this ratio.

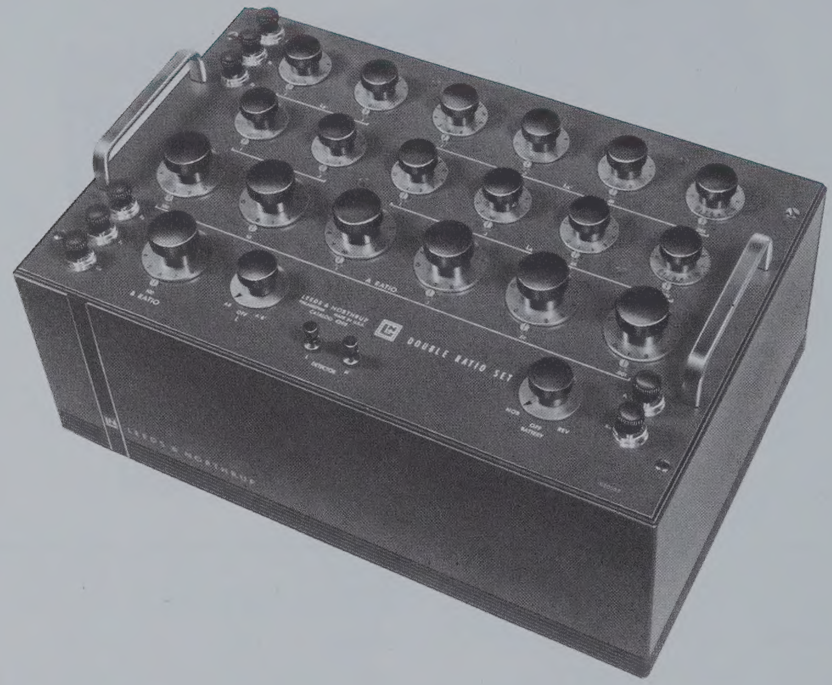
CASE—Aluminum, with dust cover; 19-5/16″ (l) x 10-3/4″ (w) x 9-3/4″ (h) including cover; weight approx. 35 lb.

PRICE—$2150.00. "-B", add $250.00.

RECOMMENDED ACCESSORIES

9834 Null Detector
4030-B Resistance Standard (11)
4001 NBS Stand, or
127287 Adjustable Mercury Stand (10)
128436 Shorting-link
128488 Copper Bar (2)
Lead Compensator for external lead resistance

4398 SIX-DIAL DOUBLE RATIO SET



BASIC RATIOS CAN BE CALIBRATED TO 1 PPM

Ratios are continuously adjustable from approximately 1:11 to 11:1

Matched critical resistors

Built-in lead compensation

Electrostatic shielding

Gold-plated copper binding posts

Convenient for two- or four-terminal measurements

Application as double ratio set, direct-reading ratio set, precision six-dial resistance box and limit bridge

This high-accuracy ratio set has multiple applications: as a double ratio set for comparing shunts, standards and low resistances; as a direct-reading ratio set; for intermediate-value resistances; and as a limit bridge. With the addition of a stable adjustable resistance, the instrument can provide direct measurements of R_t/R_o of a precision resistance thermometer. Combining speed and accuracy, the 4398 Double Ratio Set incorporates many quality features, including built-in lead compensation at all ratios, electrostatic shielding, fully enclosed switch contacts, contacts paralleled to reduce resistance, and measuring-circuit resistors wound of selected L&N Grade A manganin wire, stabilized and matched for temperature coefficient.

Important in the design are proper location of potential points for the various circuit configurations, and the design of the low-value decades of the lead compensation. Provision can be made for automated readout through data-handling equipment (add "-R" to List Number for this feature). An L&N Report of Calibration is also available (add suffix "-B").

SPECIFICATIONS

LIST NUMBERS—4398 (bench-top): 4398-1 (rack-mounting).

RATIO ARMS—"A": Six decades, spanning 100 to 1111.110 ohms in steps of 0.001 ohm. The 0.001, 0.01 and 0.1-ohm decades are Waidner-Wolff shunt-type to minimize effects of contact resistance. "B": One decade spanning 0 to 1000 ohms in steps of 100 ohms. Yoke arms "a" and "b", electrically the same as "A" and "B" respectively, are mechanically coupled to them and turn simultaneously to the same resistance setting.

RESOLUTION—1 ppm when "A" ratio is at 1000 ohms or higher.

LEAD COMPENSATION— L_A is a double four-dial adjustable resistance in series with the "A" ratio arm and having a range from 1 to 11.110 ohms. The lowest dial, which sets a 0.01-ohm slidewire, has 0.0002-ohm graduations. L_B is a double two-dial adjustable resistance in series with the "B" ratio arm and having a range from 0 to 11 ohms in steps of 0.1 ohm.

MAXIMUM VOLTAGE—1 volt per 100 ohms in ratio arms. Maximum current when used as a resistance box: 10 mA.

LIMITS OF ERROR

Magnitude	Application
20 ppm	Six-dial Double Ratio Set for Kelvin bridge (four terminal) measurements
1 ppm	Same, with corrections
1 ppm	Direct-Reading Ratio Set
±0.003%	Precision Six-Dial Resistance Box
±0.003%	Determination of ratios between fixed calibration points of resistance thermometers. Stability error of external resistance box must be added.
	Lead-Compensation Dials
±0.1%	1-ohm decade
±0.3%	0.1-ohm decade
±2%	0.01-ohm decade
±0.0005 ohm	0.01-ohm slidewire

L&N REPORT OF CALIBRATION—At the time of calibration, resistance ratio valves obtained by use of the equation and corrections given are not in error by more than 0.001%.

CASE—Metal with gray vinyl finish and lifting handles; bench-top model is supplied with a soft-vinyl dust cover. Bench-top model: 19¼″ (w) x 12½″ (h) x 9-11/32″ (d). Rack-mounting model: 19″ (w) x 12-7/32″ (h) x 7-7/32″ (d). Weight approx. 27 lb.

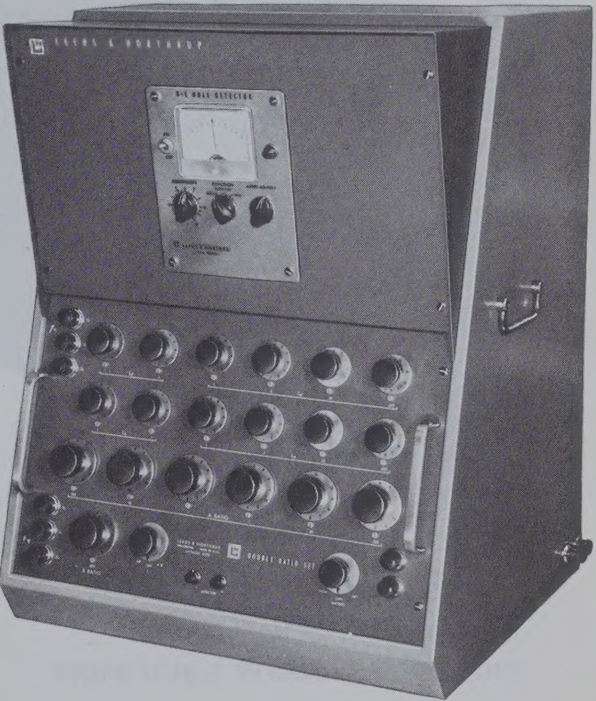
PRICE—4398 or 4398-1: $3750.00. "-R", add $400.00. "-B", add $400.00.

RECOMMENDED ACCESSORIES

9834 Null Detector
9876 Power Supply, or
Std 2233 Battery, or
7597 Storage Cell
4030-B Standards (11)
127287 Mercury Stands (10)
128436 Shorting Link
128488 Copper Bars (2)

4398-A□ SIX-DIAL DOUBLE RATIO SET FACILITY

Completely packaged and pre-wired with matched components



Completely packaged and pre-wired in compact, space-saving, table-top cabinets, these facilities provide increased operating convenience and reduced set-up time. The 4398-A10 Facility consists of a 4398-1 Double Ratio Set mounted in a console with a 9834-1 Null Detector; the 4398-A11 Facility includes a 9876-1 Power Supply as well.

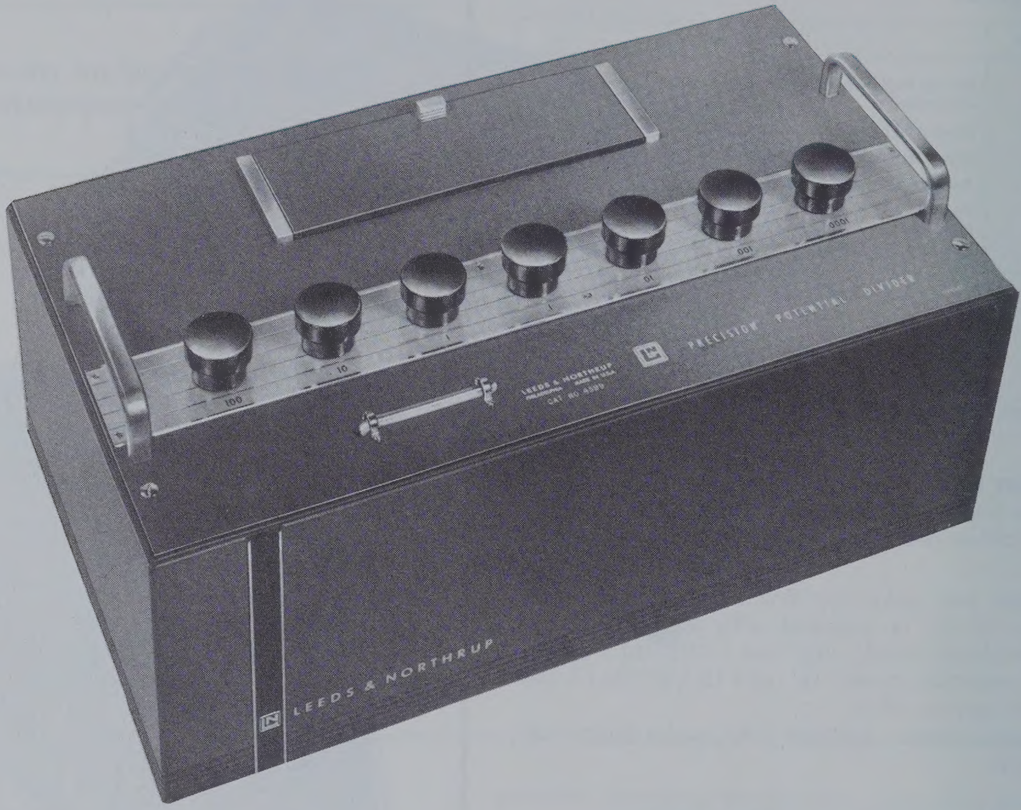
SPECIFICATIONS

POWER REQUIREMENTS—120 volts, 50/60 hertz. Operates on 100 to 130 volts; 50 watts, max.

CABINET—Metal, finished in light-gray baked enamel, with lifting handles; 22-3/16″ (w) x 27-3/16″ (h) x 18-5/16″ (d) at bottom; weight approx. 117 lb.

PRICE—4398-A10: $4445.00; 4398-A11: $4670.00. "-R", add $400.00. "-B", add $400.00.

4399 SEVEN-DIAL PRECISION POTENTIAL DIVIDER



FOR CALIBRATION OF HIGHEST PRECISION EQUIPMENT

In-line digital readout

All resistors and switches housed in thermal-equalizing chamber

Electrostatic and thermal shielding

Binding posts enclosed in shielded compartment

Low output impedance permits high detector sensitivity

End resistors to extend range by multiplier of ten

External binding posts for calibration of 2nd, 3rd, and 4th decades without removal from case

The seventh dial of the 4399 Precision Potential Divider gives a least count of 0.05 ppm—at least 10 times better than is possible with a six-dial instrument (using end resistors further improves resolution for ratios beyond 10:1). The 4399, therefore is *the* tool for calibrating the highest accuracy potentiometers, voltage dividers, and resistance standards, and for comparing intermediate-value resistors of extreme precision. This unit is basically a Kelvin-Varley slidewire and can serve as either a universal ratio set or as a voltage divider. Principal resistors are constructed of L&N Grade A manganin wire and have matched temperature coefficients. Other features include: all switches and resistors are housed in a temperature lagging chamber; metal top plate and case provide electrostatic and thermal shielding; readout is digital, and horizontally in-line; provision is made for independent calibration of the 2nd, 3rd, and 4th decades against a standard divider. Particularly important is the low impedance, resulting in superior null-detector sensitivity required for this highest precision instrument. Extra decks can be provided on each switch to accommodate wiring for automated readout through data-handling equipment (add "-R" to List Number for this feature). A Report of Calibration can be provided for these instruments at extra cost (add suffix "-B").

SPECIFICATIONS

LIST NUMBERS—4399 (bench-top); 4399-1 (rack-mounting).

INPUT RESISTANCE—2,111.1110 ohms, without range extension.

RANGE OF ADJUSTMENT—2,111.1110 units, in smallest steps of 0.0001 unit.

RESOLUTION—0.0001 unit (0.05 ppm).

RANGE EXTENSION—Two 19,000-ohm resistances, one at each end of divider circuit, permit increasing or decreasing the ratios by a factor of ten. Plug-and-block connectors permit placing each end resistor in circuit without changing leads or introducing appreciable contact resistance.

LIMITS OF ERROR—When used as a universal ratio set at 25 C, the limits of error for each pair of related readings are as follows:

Dial Changed	Standard Limit of Error	Limit of Error With Report of Calibration
100	0.002 unit	0.0003 unit
10	0.001 unit	0.0001 unit
1	0.0004 unit	0.0001 unit
0.1	0.0002 unit	0.0001 unit
Three lowest dials	0.0001 unit each	0.0001 unit

No error for dials not moved in a related pair of readings.

L&N REPORT OF CALIBRATION—Instrument individually calibrated against highest-precision standards having direct traceability to NBS. The Report gives corrections for each step of each dial.

POTENTIAL-DIVISION LIMIT OF ERROR—±1 ppm of total input.

STABILITY—Within ±1 ppm of total range for a period of one year after shipment.

IMPEDANCE TO DETECTOR — Less than 600 ohms without range extension.

MAXIMUM APPLIED POWER — 0.2 watt at 20 volts d-c maximum across divider; 1.0 watt at 150 volts d-c maximum when using range-extension resistance.

CASE—Dark gray baked-epoxy finish with satin-finish aluminum trim; 4399: extruded aluminum case with vinyl cover, 19¼″ (w) x 10¾″ (d) x 9-3/16″ (h); 4399-1: sheet-metal case, 19″ (w) x 10-11/32″ (h) x 7-7/16″ (d).

PRICE—4399 and 4399-1: $3300.00. "-R", add $350.00. "-B", add $450.00.

RECOMMENDED ACCESSORIES

9834 Null Detector
9876 Power Supply, or
Std 2233 Dry Cell
7311 Saturated Standard Cell

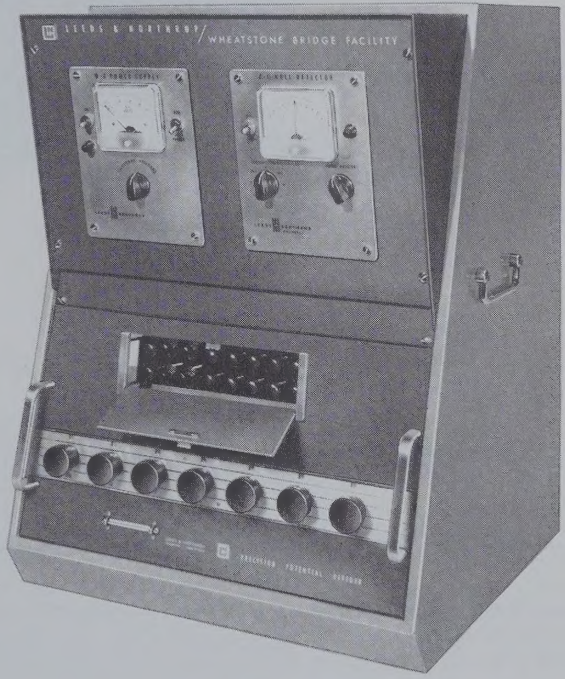
OPTIONAL ACCESSORIES

127272 Angle Bench Brackets
8401 Constant-Temperature Bath
4399-C Lead Compensator for balancing leadwires and terminal resistances when voltage dividers or universal ratio sets are connected in parallel for calibration. $730.00.

LEAD COMPENSATOR
LEEDS & NORTHRUP CO.
PHILADELPHIA

4399-A☐ SEVEN-DIAL POTENTIAL-DIVIDER FACILITY

Completely packaged and pre-wired with matched components



Each of these facilities provides a completely wired cabinet assembly with compatible accessories for operating convenience and reduced set-up time.

The 4399-A10 Facility consists of a 4399-1 Precision Potential Divider mounted in a console with a 9834-1 Null Detector; the 4399-A11 includes a 9876-1 Power Supply as well.

SPECIFICATIONS

CABINET—Metal, finished in light-gray baked enamel, with lifting handles; 22-3/16″ (w) x 27-3/16″ (h) x 18-5/16″ (d) at bottom.

PRICE—4399-A10: $3995.00; 4399-A11: $4220.00. "-R", add $350.00. "-B", add $450.00.

4393-2 UNIVERSAL RATIO SET

LEEDS & NORTHRUP

FOR USE AS UNIVERSAL RATIO SET, DIRECT-READING RATIO SET OR PRECISION RESISTANCE BOX

In-line digital ratio readout

L&N type 31 switches in main decades

All resistors housed in thermal equalizing chamber

Electrostatic and thermal shielding

Specifically designed to meet the exacting requirements of standardizing laboratories for a precise resistance-calibration instrument, the 4393-2 Ratio Set is used for the d-c comparison of odd-value resistors with certified fixed resistance standards, and the calibration of precision potentiometers. It can also be used as a 5-dial direct-reading ratio set for nominal ratios of 1:1, 5:1 and 10:1, a 6-dial precision resistance box, and a microvolt potentiometer for comparing reference-voltage sources such as standard cells. Design features include: all resistors are housed in a thermally-lagged chamber; principal resistors have matched temperature coefficients; Type 31-3 enclosed silver-alloy switches are used in all main decades; binding posts are gold-plated copper with acrylonitrile insulation, and the metal top plate and box provide complete electrostatic shielding. Provision is made for making a direct check of the resistance variations of all settings of the five lower decades. A 19,000-ohm resistor has been added to each end of the 2111.11-ohm resistor string to permit increasing or decreasing the dial ratios by a factor of 10, by a plug-and-block arrangement. In-line digital dual-color ratio readout reduces possibilities of reading errors. An L&N Report of Calibration is available as an extra cost option (add suffix "-B").

SPECIFICATIONS

USE AS 6-DIAL UNIVERSAL RATIO SET—Total nominal resistance is 2111.110 ohms; adjustable range is 20 x 100 + 10(10 + 1 + 0.1 + 0.01 + 0.001) ohms. When used as ratio device the following limits of error apply at 25 C: (1) ±0.002% for ratio settings involving one or more steps above the zero position on the "100" dial. (2) For typical ratio settings involving changes in dials below 100, the accuracy of reading is within two steps on the 0.001 dial. Instrument is generally calibrated by user, in which case correction data to 0.1 ppm is attainable.

USE AS 5-DIAL DIRECT-READING RATIO SET—Adjustable arm can be varied from 944.445 to 1055.555 ohms giving range of approximately ±5.5% Resolution is ±1 ppm. Limit of error of ±2 ppm may be obtained when comparing resistors which have values within 0.5% of each other, ±5 ppm for resistors which differ by more than 0.5%.

USE AS 6-DIAL RESISTANCE BOX—Range is 0 to 2111.11 ohms; 20 x 100 + 10 x (10 + 1 + 0.1 + 0.01 + 0.001) ohms. Change of each step above zero residual is nominal value ±(0.01% + 0.005 ohm). Residual zero resistance will not exceed 0.02 ohm.

L&N REPORT OF CALIBRATION—At the time of calibration, resistance changes obtained by the use of the supplied data are not in error by more than 0.001% for changes of 100 ohms or more, nor by more than 0.001 ohm for smaller changes.

APPLIED VOLTAGE—Customarily 2 to 4 volts d-c; up to 50 volts d-c may be applied if permitted by apparatus under test.

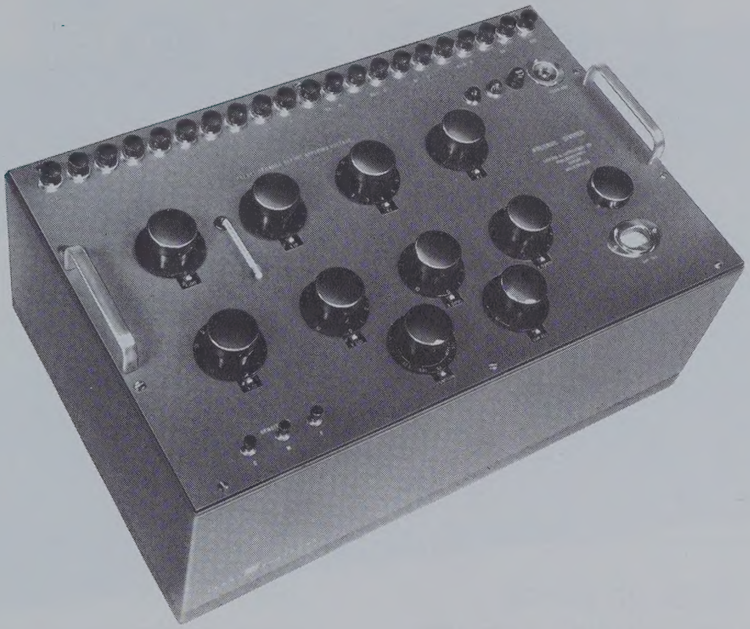
CASE—Metal case and dust cover; 24" (w) x 8½" (h) x 10" (d); weight including lid, approx. 37 lb.

PRICE—On request.

RECOMMENDED ACCESSORIES

9834 Null Detector
127272 Angle Bench Brackets

DIRECT-READING VOLTAGE DIVIDER WITH STANDARD-CELL REFERENCE



This highly-accurate Direct-Reading Voltage Divider* has been designed so that the output voltage is equal to that of a standard cell when the input resistance has been adjusted for 1 mA current flow through the divider. The range of measurement with direct reference to a standard cell is from 2 to 1100 volts. This range may be reduced to 0.02 to 11 volts (with decreased accuracy) by the use of a built-in Lindeck potentiometer.

Principal resistors are housed in a chamber whose internal temperature is controlled at approximately 35 C to within ±0.01 C. Accuracy is approximately ±0.005% from 2.0 to 1100 volts without applying corrections; there is a slight decrease in accuracy for measurements on the lower ranges.

In operation, decades are preset to the approximate value of the voltage to be measured, and the function switch is set to a standard cell to make an approximate balance before the reference cell is used. The unknown voltage is then applied and the resistance decades are adjusted to give a null balance. When this balance is reached, the reference cell is switched in and a final balance is made against it. Balancing in this manner minimizes the chance of damaging the reference cell. Since the system is direct-reading, the dial setting indicates the applied voltage.

SPECIFICATIONS

RANGE—1100 volts in steps of 10 microvolts (on X 1 range).

MULTIPLIERS—1, 0.1 and 0.01.

DECADES—8, having steps of 10 x (100, 10, 1, 0.1, 0.01, 0.001, 0.0001 and 0.00001) volts. First three decades are enclosed in a temperature-controlled chamber at 35 C. Binding posts make the decades available for use as a resistance standard, with a range of 2000 ohms to 1.1 megohms in steps of 0.01 ohm. Accuracy of first three decades is ±0.01%; of others, ±0.05%. (Accuracies stated are guaranteed for one year from date of shipment.)

STANDARD CELL SLIDEWIRE—5″ slidewire calibrated 1.0180 to 1.0201 volts, settable to 1 microvolt.

FUNCTION SWITCH—9-position, marked "STD (SC1, SC2, SC3) MEAS (0.01, 0.1, 1, SC1, SC2, SC3)".

CURRENT-ADJUSTING RHEOSTAT—10,000 ohms (10-turn) plus 150-ohm vernier.

BINDING POSTS—21. One pair each for BA and GA, 3 pairs for connecting 3 standard cells, 2 for input (A+, E−), 8 for checking purposes in measuring circuit, one GRD for shielding.

KEYS—3 for detector sensitivity, marked C, M, F.

CASE—Metal case and top-plate with GRD terminal provide electrostatic shielding; 24″ (w) x 15″ (d) x approx. 6½″ (h).

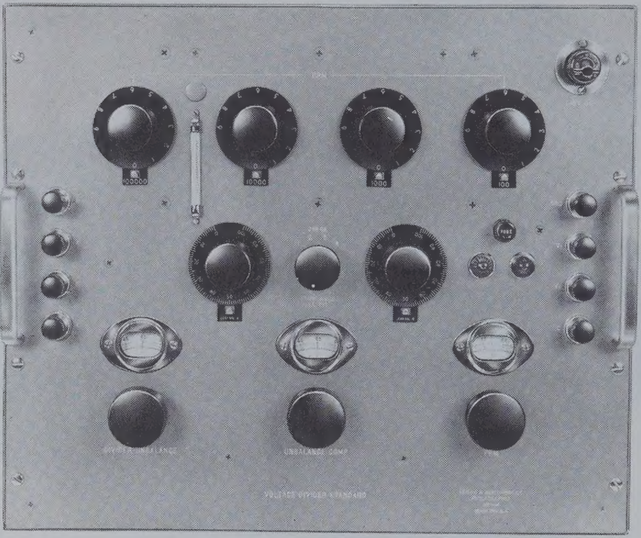
PRICE—$6000.00.

RECOMMENDED ACCESSORIES

9834 Null Detector
7597 2-V Battery

**Sandia Corporation Reprint SCR-567, October 1962, by R. P. McKnight.*

4396 VOLTAGE DIVIDER STANDARD



±0.5 PPM LIMIT OF ERROR WHEN CORRECTION DATA IS APPLIED

Constant-temperature chamber for principal resistors

Transistorized heater-control circuit, mercury-contact regulator

Electrostatic shielding, thermally-lagged aluminum case

Auxiliary slidewires compensate for lead and contact resistance

Zero-offset slidewires to permit direct reading of calibration error

An indispensable tool for standardizing and calibration laboratories, the L&N 4396 Precision D-C Voltage Divider Standard is a high-accuracy, four-dial-plus-slidewire instrument for conveniently checking or calibrating highest-precision voltage dividers. Construction features include complete electrostatic shielding, all resistors made of L&N Grade A manganin wire to exacting specifications, Type 31 Switches used throughout to assure low, stable contact resistances, all critical resistors and switches enclosed in a constant-temperature chamber, and acrylonitrile binding posts. In addition, auxiliary slidewires are provided to permit compensation for the effects of lead and contact resistances, and to provide zero offset; auxiliary circuits and switches facilitate convenient checking by self-calibration.

SPECIFICATIONS

RANGE—0 to 1,000,000 units of voltage division.

TOTAL INPUT RESISTANCE—100,000 ohms ±0.01%.

MAXIMUM INPUT VOLTAGE—100 volts d-c for rated accuracy.

LIMIT OF ERROR—±0.0003% in ratio (±3 ppm) without corrections. Corrections are supplied which, at the time of calibration, are accurate to within ±0.5 ppm.

READOUT—Four decade-switch dials and a five-inch slidewire. Switches have steps of 9(100,000 ppm), 9(10,000 ppm), 9(1000 ppm), 9(100 ppm). Slidewire has 200 calibrated divisions of 0.5 ppm, and resolution of 0.1 ppm.

AUXILIARY CIRCUITRY—In addition to the basic voltage-divider circuit, auxiliary switches and slidewires are provided to permit interchecking and calibration of a pair of Voltage Divider Standards, or checking a Voltage Divider Standard against a series of ten matched resistors. Additional items include: two calibrated five-inch-diameter slidewires, two calibrated two-inch-diameter slidewires, one six-position function switch.

CONSTANT-TEMPERATURE CHAMBER—Chamber, heated by a full-wave rectified current from a 120-volt, 60-hertz line, is controlled to nominal temperature of 35 C by means of a mercury-contact thermometer and special transistorized heater-control circuit.

CASE—Thermally-lagged extruded aluminum case with engraved aluminum top-plate and separate metal dust-cover. 19¼″ (l) x 16″ (w) x 10¾″ (d); weight approx. 55 lb.

PRICE—$5500.00.

RECOMMENDED ACCESSORIES

9834 Null Detector
Std 2233-7 45-V Battery (2 required)

4395 PRECISION VOLTAGE DIVIDER

A
IN
B
GRD
A
OUT
C
LEEDS & NORTHRUP
PHILADELPHIA
MADE IN U.S.A.
CATALOG NO 4395
100 000 OHM VOLTAGE DIVIDER
10000
1000
100
SENSITIVITY
LOW
MEDIUM
HIGH

HIGH RESOLUTION (1 PPM)

In-line digital readout

Electrostatic shielding

L&N type 31 switches

Acrylonitrile-insulated binding posts

The 4395 Voltage Divider provides a precise means of dividing a known d-c or a-c voltage into parts. The known voltage is applied to the input terminals and the three ratio dials and slidewire are adjusted to obtain a desired fraction of the input voltage at the output voltage terminals. This instrument is particularly useful in checking linear and non-linear slidewire potentiometers and attenuators. Features include totally-enclosed Type 31 switches, woven-type main resistors, electrostatic shielding, acrylonitrile-insulated binding posts, and in-line digital readout. An L&N Report of Calibration is available (add suffix "-B").

SPECIFICATIONS

LIST NUMBERS—4395 (bench-top); 4395-1 (rack-mounting).

INPUT RESISTANCE—100,000 ohms ±0.1%.

RATIO DIALS—Three, adjustable in fixed steps of 9 x 10,000, 9 x 1000, and 9 x 100.

RATIO SLIDEWIRE—Continuously adjustable, calibrated 0 to 100, smallest scale division 5 ppm, resolution 1 ppm.

LIMIT OF ERROR—±1 main slidewire division for any setting from 1 to 100,000.

L&N REPORT OF CALIBRATION—Values obtained by application of the corrections to the individual dial and slidewire settings or the summation of any combination thereof are correct within 0.5 dial unit (5 ppm).

INPUT-VOLTAGE RATING—200 volts d-c continuous; 300 volts d-c for test periods of about ½ hour.

TERMINALS—Two input, two output and case ground.

KEYS—Three; sensitivity controls for detector.

CASE—4395: Metal with vinyl dust cover; 19¼″ (w) x 9″ (h) x 7½″ (d); weight approx. 12 lb.; 4395-1: 19″ (w) x 9″ (h) x 5-5/8″ (behind relay rack).

PRICE—4395 and 4395-1: $675.00. "-B", add $180.00.

RECOMMENDED ACCESSORIES

9834 Null Detector, or
2340-d Galvanometer, or
2435-d Galvanometer

SLIDEWIRES

L&N provides three calibrated slidewires for instruments to be assembled from basic components. Each of these compact slidewires can be used conveniently to obtain the simplest ratio arms of a Wheatstone bridge. For equipment to complete your circuit, refer to the sections on Standards, and on Galvanometers, Detectors and Power Supplies.

4258 KOHLRAUSCH SLIDEWIRE

DESIGNED PRIMARILY AS AN ADJUSTABLE RATIO FOR WHEATSTONE-BRIDGE CIRCUITS

End resistors for extending range and resolution

Used principally as an adjustable ratio for Wheatstone-bridge circuits in the measurement of electrolytic conductivity, the Kohlrausch slidewire is a helix wound on an insulating drum. A sliding contact, attached to a rotating hood covering the drum, is moved along the wire by rotating this hood. Numbers of turns are read on a vertical scale in front of the hood, and the exact proportion of a turn is read on a scale on the lower periphery of the drum.

SPECIFICATIONS

SLIDEWIRE—About 15′ long, in 10-turn helix; resistance about 7 ohms.

SCALE—Vertical, 10 divisions; circular, 100 unit divisions with half divisions indicated.

LIMIT OF ERROR—±0.25 unit-division.

CURRENT RATING— 0.5 A.

END RESISTORS — Two: resistance of each is 4.5 times that of slidewire, within ±0.04%.

CASE—Metal, gray enamel finish; 9¼″ x 11″ x 8-7/8″; weight approx. 14 lb.

PRICE—$960.00 each in lots of 1 to 9. For 10 or more, $640.00 each.

4261 CIRCULAR SLIDEWIRE

DESIGNED PRIMARILY AS AN ADJUSTABLE RATIO FOR WHEATSTONE-BRIDGE CIRCUITS

End resistors for extending range and resolution

LEEDS LN NORTHRUP

When the higher resolution of the Kohlrausch slidewire is not required, the circular slidewire can be used. The slidewire is wound on an insulated circular mandrel mounted on the edge of a rotatable disk. The scale on this disk is read through a window in the top-plate.

SPECIFICATIONS

SLIDEWIRE—About 14″ long; resistance about 100 ohms.

SCALE—100 divisions (each divided in half).

LIMIT OF ERROR—±0.5 division.

CURRENT RATING—0.1 A.

END RESISTORS—Two: resistance of each is 4.5 times that of slidewire, within ±0.1%.

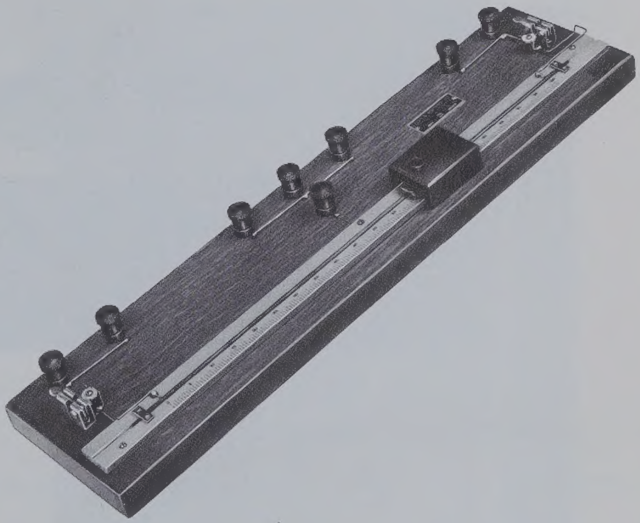
CASE—Metal, gray enamel finish; 7-5/16″ x 8-1/16″ x 5½″; weight approx. 4½ lb.

PRICE—On request.

4203 STUDENTS' SLIDEWIRE

FOR TEACHING THE APPLICATION OF AN ADJUSTABLE RATIO IN A WHEATSTONE-BRIDGE CIRCUIT

Exposed construction and straight slidewire and scale for visual comprehension



Designed as an aid in demonstrating to the elementary student the application of an adjustable ratio in Wheatstone-bridge circuits, this slidewire is wound on a *straight* insulated mandrel and mounted on a plastic scale. A helical winding provides much higher resistance than a solid wire having the same length as the mandrel, and provides greater sensitivity.

SPECIFICATIONS

SLIDEWIRE—16″ long; resistance about 42 ohms.

SCALE—100 divisions (each divided in half).

LIMIT OF ERROR—±1 division.

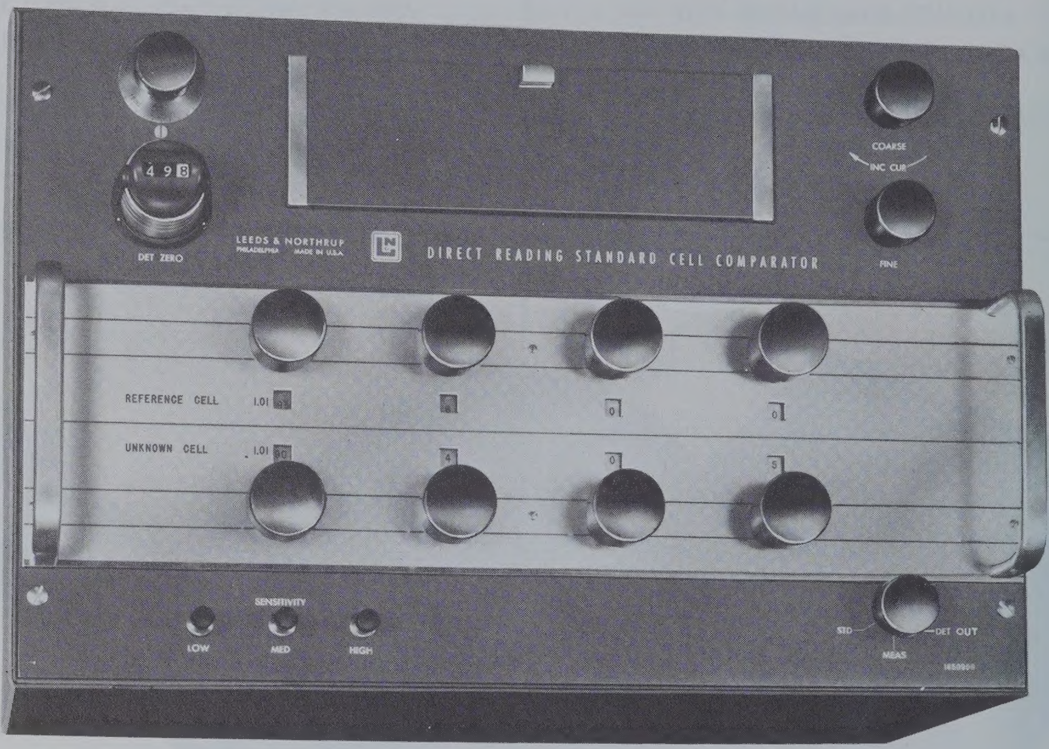
CURRENT RATING—0.2 A.

END RESISTORS—Two: resistance of each is 4.5 times that of slidewire, within ±0.15%.

CASE—Oak base; 21″ x 5″ x 2½″; weight approx. 4 lb.

PRICE—$180.00.

7565 DIRECT-READING STANDARD-CELL COMPARATOR



DIRECT READOUT OF STANDARD CELLS TO 0.1 MICROVOLT

In-line digital readout of reference and standard-cell voltages

Matched resistors

Single compensator for internal and external thermal emfs

Electrostatic and thermal shielding

Duplicate circuits for establishing reference and unknown cell voltages

The 7565 Comparator is designed to determine the voltage of standard cells conveniently and directly. Although the instrument circuit measures the difference in voltage between the unknown cell and a reference standard, the dials show the actual voltage of each for direct readout with no computation. This instrument provides an accuracy of ±0.1 μV in the usual application—consistent with the highest-quality saturated standard cells. The twin measuring circuits—L&N adaptions of the six-dial potentiometer—provide a stable voltage drop and low output resistance at all dial settings. Design features which contribute to the high accuracy are: electrostatic shielding, case insulation to provide thermal stability for circuits and terminal enclosure, construction techniques to keep thermal emfs to a minimum, a compensator to eliminate residuals and critical resistors wound from the same spool of manganin wire and aged for stability.

Operation is routine and easily mastered. Only the detector need be observed during operation; readout on the comparator is digital and in-line. Provision for automatic readout is available; add suffix "-R". An L&N Report of Calibration is also available (suffix "-B").

SPECIFICATIONS

LIST NUMBERS—7565 (bench-top); 7565-1 (rack-mounting).

RANGE—Span of 2300 μV over the range of 1.017 5000 to 1.019 8000 volts.

RESOLUTION—0.1 μV.

LIMITS OF ERROR—±0.1 μV when difference between reference and unknown is 1000 μV or less; increasing to 0.2 μV at 2300 μV difference.

L&N REPORT OF CALIBRATION—Differences of less than 1000 μV between Reference Cell and Unknown Cell are correct to 0.1 μV. Differences of 1000 μV or more are correct to 0.2 μV.

CIRCUITS—Three: comparison, standardizing and thermal-compensating, electrostatically shielded.

FUNCTION SELECTION—Three-position rotary switch.

DETECTOR SENSITIVITY KEYS—Three, low-thermal.

STANDARDIZING CURRENT ADJUSTMENT—Two rheostats.

TERMINALS—Ground and two pairs. All terminals in hinged-top enclosure with magnetic latch.

POTENTIOMETER CURRENT SOURCE—1.35-volt mercury cell.

THERMAL COMPENSATING POWER—1.35-volt mercury cell.

MERCURY-CELL DRAIN—500 μA maximum. Battery life, normally more than one year.

CASE—Extruded aluminum with thermal insulation; soft vinyl dust cover; 7565: 19¼″ (w) x 12½″ (h) x 8¾″ (d); 7565-1: 19″ (w) x 12¼″ (h) x 8-5/16″ (d).

PRICE—7565 and 7565-1: $3450.00. "-R", add $200.00. "-B" add $200.00.

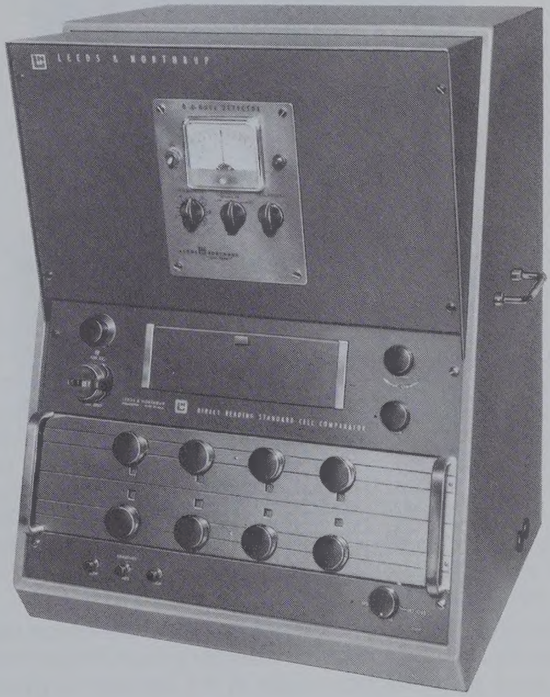
RECOMMENDED ACCESSORIES

9834 Electronic Null Detector
7308 Auxiliary Cell
127272 Angle Bench Brackets

7565-A10 DIRECT-READING STANDARD-CELL COMPARATOR FACILITY

Complete assembly of compatible components

D-c null detector—fast response, high impedance



This comparator facility combines the 7565-1 Direct-Reading Standard Cell Comparator, a 9834-1 D-C Null Detector, a 7308 Auxiliary Standard Cell and all necessary cabling and inter-connections in a convenient sloped-front metal cabinet.

SPECIFICATIONS

POWER REQUIREMENTS—120 volts, 50/60 hertz, 18 watts.

CABINET—Metal, finished in a durable light-gray baked enamel, with lifting handles; 22-3/16″ (w) x 27-3/16″ (h) x 18-5/16″ (d) at bottom; weight approx. 115 lb.

PRICE—$4180.00. "-R", add $200.00. "-B", add $200.00.

ACCESSORY

7311 Bank of Saturated Standard Cells

8693-A12-127-□□□ DIRECT-READING THERMOCOUPLE COMPARATOR

PROVIDES CHOICE OF 32 STANDARD THERMOCOUPLE RANGES; SPECIAL RANGES AVAILABLE

Double range: millivolt and thermocouple

Temperature range has automatic reference-junction compensation

Sixteen-thermocouple capacity

Will operate with grounded couples

Recorder provides direct reading of thermocouple error and correction

All components prewired in each cabinet for convenient operation

Providing a rapid new approach to the comparison of a group of similar thermocouples with a reference thermocouple of the same type, the Direct-Reading Thermocouple Comparator finds application in inspection departments, instrument maintenance laboratories, secondary standards laboratories and aircraft-engine test and repair depots. Readout, in the form of a permanent chart record, indicates the deviation of each thermocouple from the reference or from the standard calibration curve directly in degrees F or C at the temperature established by your checking furnace.

The comparator facility combines a double-range temperature potentiometer with selector switch for connecting each of 16 thermocouples to the measuring circuit, a power supply for the potentiometer, and a zero-center, adjustable-span Speedomax H recorder. All components are mounted and prewired in a slope-front metal cabinet designed for convenient operation. A wide choice of thermocouple ranges is available for the primary range; a 0-25 millivolt range is provided as the secondary range for miscellaneous measurements. Furnace temperature measurements are determined with the potentiometer; temperature differences, automatically by the recorder.

SPECIFICATIONS

RANGE—Double range. Millivolt range, 0 to 25 mV (suffix "127"); thermocouple range is selected from 32 standard ranges (see table on next page for final suffix). Temperature range has automatic reference-junction compensation; millivolt range requires thermometer measurement of reference - junction temperature. Special ranges available on request.

LIMITS OF ERROR—Temperature: ±0.2% of the temperature range. Temperature difference: ±0.5% of the recorder span.

FUNCTION SWITCH—A six-position switch providing an OUTPUT, MEASURE and RECORD position for both thermocouple and millivolt range.

THERMOCOUPLE SELECTOR SWITCH—A sixteen-position switch for connecting thermocouples to measuring circuit.

READOUT—For furnace temperature. Readings for both ranges appear in a central readout window and are read directly from the slidewire scales. Two two-turn slidewires provide a calibrated scale 27.5 inches long for each range, each continuously adjustable over the span of its range.

INPUTS—Sixteen thermocouple inputs can be connected at the rear terminal board. Selection of any of these inputs is made by the THERMOCOUPLE SELECTOR SWITCH. Connection to the millivolt range is made through an additional pair of terminals.

OUTPUTS—The output potentials of the thermocouples, selected by the THERMOCOUPLE SELECTOR SWITCH, are connected to the potentiometer when the function switch is in the MEAS position, to the recorder when it is in the REC position. The output of the potentiometer is connected to the recorder when the function switch is in the OUTPUT position.

POWER SUPPLY—Potentiometer is powered by a line-operated constant-voltage power supply. Input: 107 to 127 volts, 50/60 hertz.

Type of Thermocouple	Range	Smallest Scale Division	Suffix No.
Iron & Constantan	0 to 300 F	0.5 F	048
	−100 to +500 F	1.0 F	009
	0 to 1000 F	2.0 F	003
	400 to 1200 F	2.0 F	172
	0 to 1600 F	5.0 F	142
	0 to 2000 F	5.0 F	049
	900 to 2000 F	2.0 F	164
	−55 to 105 C	0.5 C	513
	0 to 200 C	0.5 C	007
	−100 to +400 C	1.0 C	166
	0 to 500 C	1.0 C	022
	0 to 800 C	2.0 C	057
	0 to 1100 C	2.0 C	165
Chromel & Alumel	0 to 700 F	2.0 F	200
	0 to 1200 F	2.0 F	024
	0 to 2000 F	5.0 F	001
	0 to 2500 F	5.0 F	143
	1000 to 2500 F	5.0 F	046
	0 to 600 C	1.0 C	062
	0 to 1200 C	2.0 C	047
	500 to 1200 C	2.0 C	167
Plat., 10% Rhodium & Platinum	0 to 2500 F	5.0 F	033
	0 to 3200 F	5.0 F	144
	2000 to 3200 F	2.0 F	052
	0 to 1600 C	5.0 C	067
Plat., 13% Rhodium & Platinum	0 to 3200 F	5.0 F	145
Copper & Constantan	−340 to +230 F	−340 to −100 F: 2.0 F −100 to +230 F: 1.0 F	168
	−100 to +400 F	1.0 F	032
	0 to 650 F	2.0 F	201
	−200 to +150 C	−200 to −150 C: 2.0 C −150 to +50 C: 1.0 C 50 to 150 C: 0.5 C	170
	−100 to +300 C	1.0 C	146
	0 to 400 C	1.0 C	169
Millivolts	0 to 25	0.05	127

RECORDER

TYPE—Zero-center, adjustable-span strip-chart recorder.

RECORD—Single-point, continuous line.

ELECTRICAL SPAN—Adjustable between 0.3 and 50 mV; setability better than 0.5 μV. The two-stage span adjustment is made by means of a 10:1 multiplier switch and a single knob for coarse and fine adjustment.

SPAN STEP-RESPONSE-TIME RATING—One second, nominal.

DEAD BAND—0.15% of span.

CHART AND SCALE—6½″ wide; 100 divisions; numerals 10-8-6-4-2-0-2-4-6-8-10; overtravel, provided at low and high ends of scales, is convenient for adjusting scale span in F or C.

CHART SPEED—240″ per hour.

POWER SUPPLY—Recorder operates on 120 volts, 60 or 50 hertz, as specified.

CABINET—Metal, with lifting handles; recorder equipped with removable gasketed door and glass window; 22-3/16″ x 27-3/16″ x 18-5/16″; weight approx. 100 lb.

PRICE—$1840.00.

RECOMMENDED ACCESSORIES

9009 Thermocouple Calibrating Furnace

1553 CAMPBELL-SHACKELTON SHIELDED A-C RATIO BOX

FOR MEASUREMENTS OF CAPACITANCE AND CONDUCTANCE, INDUCTANCE, POWER FACTOR, DIELECTRIC CONSTANT, AND ELECTROLYTIC CONDUCTIVITY

Serves as the nucleus of a variety of one-to-one bridges for impedance measurements

The Campbell-Shackelton Ratio Box is used in the construction of a variety of capacitance, dielectric, power factor and inductance bridges.

SPECIFICATIONS

RATIO ARM—Two 1000-ohm resistors, adjusted alike to ±0.01% in resistance and to ±0.2 pF residual capacitance.

TRANSFORMER—Double-shielded input transformer for frequencies from 200 to 50,000 hertz; maximum applied potential, 25 volts.

CAPACITANCE AND RESISTANCE—Auxiliary capacitance and resistance for obtaining initial balance with grounded "D" point or with Wagner earth-connection.

TERMINALS—Shielded, all-metal construction.

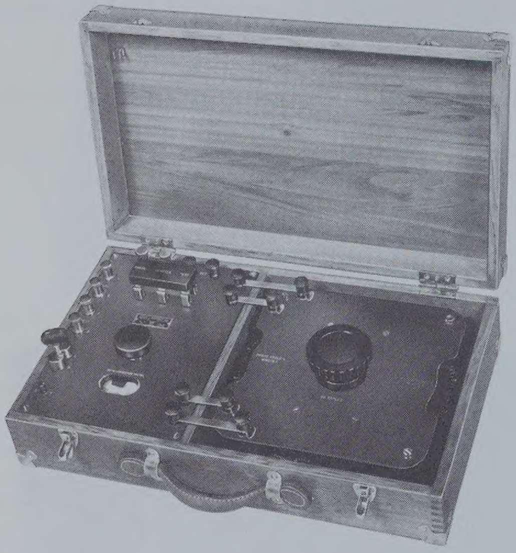
CASE—Metal, 10″ x 5½″ x 5¾″; weight approx. 17 lb.

PRICE—$1150.00.

7151 SILSBEE CURRENT TRANSFORMER TEST SET

For continuous secondary current ratings up to 10 amperes

Reads current ratio and phase angle



The 7151 Test Set is used for the comparison of 60-hertz instrument transformers with a certified standard transformer. It is designed for continuous secondary current ratings up to 10 amperes. Terminals are provided for connections to an external detector. An L&N Report of Calibration is available (add suffix "-B").

SPECIFICATIONS

Range	Accuracy of Adjustment
Ratio Correction Factor 0.99 to 1.01 Ratio Correction Factor 0.95 to 1.05	±0.0002 RCF ±0.001 RCF
Phase Angle −45 to 0 to +45 minutes Phase Angle −225 to 0 to +225 minutes	±2 minutes ±6 minutes

CASE—Oak, with carrying handle; 20¼″ (l) x 12″ (w) x 6″ (h).

PRICE—$1750.00; "-B", add $400.00.

RECOMMENDED ACCESSORIES

9844-60 A-C Null Detector

– – A-c ammeter of moderate accuracy for test currents to 10 amperes

– – 120-volt, 60-hertz autotransformer and loading transformer for tests involving heavy primary currents.

7156 Set of Adjustable Burdens. Price $2100.00.

7161 POTENTIAL TRANSFORMER TEST SET

For potential transformers having 120-volt, 60-hertz secondary windings

Reads voltage ratio and phase angle

The 7161 Test Set is used for the comparison of 60-hertz instrument potential transformers with a certified standard transformer. It is designed for potential transformers having 120-volt, 60-hertz secondary windings. Terminals are provided for connection to an external detector.

SPECIFICATIONS

Range	Accuracy of Adjustment
Ratio Correction Factor 0.98 to 1.02	±0.0004 RCF
Phase Angle −90 to 0 to +90 minutes	±4 minutes

CASE—Oak, with carrying handle; 14⅜″ (l) x 10⅜″ (w) x 6¼″ (h).

PRICE—$830.00.

RECOMMENDED ACCESSORIES

9844-60 A-C Null Detector

– – A-c voltmeter of moderate accuracy for test voltages to 120 volts

7156 Set of Adjustable Burdens. Price $2100.00.

Note: Test sets similar to the 7151 and 7161 can be built to order for use at other frequencies such as 25, 50 and 400 hertz. For information contact the Leeds & Northrup office in North Wales, Pa. stating frequency and desired scale ranges.

D

BRIDGES

Introduction D-1
Multi-Terohm Bridge D-9
Wheatstone Bridges D-10
Temperature Bridges D-18
Kelvin Bridges D-25
Dielectric Bridges D-30
Conductivity Bridges D-32

LEEDS & NORTHRUP / WHEATSTONE BRIDGE FACILITY
D-C POWER SUPPLY
D-C NULL DETECTOR
SENSITIVITY
FUNCTION
ZERO ADJUST
LEEDS & NORTHRUP

BRIDGES

A resistor bridge is a network of four or more resistors which permits the direct measurement of resistance. If the absolute value of one and the ratio of two others is known, the absolute value of the fourth can be readily determined. In addition to the basic circuit of four or more elements, a power supply and detector are required to complete the system.

For general measurements of resistance and impedance, and for a number of specific quantities which can be measured in terms of resistance or impedance, Leeds & Northrup builds an extensive variety of d-c and a-c bridges. You'll find a suitable standard model listed in this chapter for most measuring, testing or calibrating applications; for unusual problems we have probably built either a modified standard bridge or a special one which might fill your needs.

FACTORS IN MEASURING RESISTANCE

DEVIATION VS NULL METHOD—In normal use of bridges, a measurement is made in a balanced condition, when a null is indicated by a detector between diagonally opposite bridge "corners". Under these conditions the value of the power-supply voltage and the calibration of the null detector have no first-order effect upon the accuracy of the measurement; the measurement accuracy depends primarily upon the value of the resistors in the bridge arms.

It is also possible to make bridge measurements under unbalanced conditions, by properly interpreting the effect of null-detector deflection. However, this normally results in a non-linear relationship between detector deflection and resistance variation. In addition, the resistance measurement will be dependent upon both the power-supply voltage and the calibration of the null detector. Nonetheless, the deviation method is often convenient and adequately precise when measuring relatively small resistance differences or deviations.

EFFECT OF POWER SUPPLY—One alternate technique of measuring resistance is the ohmmeter method. This consists of applying a known voltage across a resistor and measuring the current with a device calibrated directly in resistance. The precision of this method is limited by the fact that the measurement is directly affected by the magnitude of the power-supply voltage, and that a calibrated current-measuring device is required. Furthermore, there is no straightforward way of eliminating the effects of lead resistance.

Another alternative is the volt-ampere method. This consists of measuring the voltage across a resistance and the current through it, then computing the resistance. An important requirement of this method is that at least two power supplies in the measuring system must be constant in ratio. An advantage is that effects of lead resistances may be eliminated.

These methods contrast with bridge measurements in which the power-supply level is not normally a direct factor, and where measurements can usually be achieved with a single balance.

LEAD RESISTANCE—In making bridge measurements the effects of lead resistance should be considered. The effect is normally greater when low values of resistance (10 ohms or less) are being measured. A number of refinements of the basic bridge circuit have been devised to reduce this effect.

Among the most common are the Kelvin Bridge and the Mueller Bridge. Basically these bridges provide a first-order correction for lead-resistance effects, but may require multiple balances for complete elimination.

RANGING—The range of resistance over which a bridge is intended to measure determines many aspects of its design. For example, a bridge for measuring low values of resistance presents the lead-resistance problems referred to previously. In addition, some of the bridge elements themselves should also be of low resistance value. This may mean that these resistors must be capable of carrying high currents without a significant change in resistance due to heating and that the switching devices used in the bridge circuit be of adequately low and stable contact resistance.

In the measurement of very high values of resistance, the effects of leakage paths around the bridge element become more significant, so that insulation of components and interconnections becomes a prime factor. (Leakage paths may be avoided to some extent by specialized circuitry.) Furthermore, the stability of resistors of very high value is less than that obtainable for resistors of lower value.

LEAKAGE—While leakage effects are a major factor in measurements of high resistance, they are also important in precise measurements of lower values under conditions of high humidity. The most straightforward way to deal with this problem is to provide adequate insulation. However, in some situations it may not be practical to limit the leakage currents in this manner; the technique known as guarding is then applied, to divert leakage currents away from critical paths. For a more detailed description of guarding, refer to page A-19.

STABILITY—In making bridge measurements, it is important that measuring resistors be stable with time and with changes in temperature and humidity. In some situations it is sufficient to have stability of ratio. For highest accuracy, resistors are sealed within a controlled temperature chamber. Switches should have low and stable contact resistance, low thermal emfs and high insulation resistance. For a description of L&N Type 31 switches and resistors made of L&N Grade A manganin wire, refer to page A-18.

APPLICATION OF BRIDGES

For measurements of electrical resistance, the simple Wheatstone bridge is generally used for resistance greater than one ohm, while the Kelvin double bridge is used for resistance less than ten ohms. For measurements in the terohm range, a multi-terohm bridge is available (4233-A11). Specialized versions of the Wheatstone bridge adapt it for use in numerous other applications, such as measuring temperature, conductivity and humidity; fault-location in communication and power cables; rapid inspection of magnetic windings, etc. The table on page D-3 lists typical applications of the various types of bridges and the characteristics which are important for each of these areas of measurement.

Brief descriptions of how bridges are used for measuring various quantities follow. A selection guide (based on range and accuracy) for multi-terohm, Wheatstone, Kelvin, temperature and conductivity bridges at the end of this introduction is designed to assist you in quickly locating the L&N bridge best suited to your particular application. Detailed descriptions, specifications, and illustrations of all L&N bridges follow.

Area of Measurement		Type of Bridge	Typical Applications	Characteristics & Requirements
D-C	Resistance (Multi-Terohm)	Wheatstone	Determination of resistance of insulators and semi-conductors	Leakage most important High-voltage capability Means of calibration required
	Resistance (High Range)		Manufacture and adjustment of high precision resistors Inspection of resistive components Location of faults in telephone and communication cables	Flexibility for 2, 3, or 4-lead measurements Lead effect for 10 ohms or less important Leakage important above 10 megohms Convenience of operation desirable
	Temperature	Mueller	Calibration of thermometers Measurement of boiling/freezing points Calorimetry	Accommodate 2, 3 and 4-lead thermometers (also loop thermometers for difference measurements)
	Resistance (Low Range)	Kelvin	Determination of wire resistance Determination of contact resistance Calibration of shunts Motor-temperature measurement	Permits 4-lead measurement of resistance Measure 10 ohms or less High current levels
A-C	Dielectric Properties	Schering	Impedance characteristics of power cables, insulating oils and insulating materials	Measure at high voltages and relatively high currents Balance is made with bridge corner at ground potential
	Electrolytic Conductivity	Jones Conductivity/ Resistivity	Determination of nature of solutions	Measure a-c resistance Provide temperature compensation Eliminate polarization effect

D-C MEASUREMENTS

MEASURING RESISTANCE GREATER THAN ONE OHM

The Wheatstone bridge is a manually balanced instrument which is used for measuring resistances as high as a megohm or more. The simple Wheatstone bridge is primarily a group of four resistors connected as shown in the simplified diagram in Figure 1.

The unknown resistor is connected across the terminals X_1 and X_2. The three remaining arms consist of two ratio arms, A and B, and a decade balancing arm S. When the bridge is balanced, the unknown resistance is calculated from the equation $X = \frac{A}{B}S$. In measuring resistances with a Wheatstone bridge, the bridge is used in conjunction with a battery or power supply and a galvanometer or other null detector.

After the unknown resistor is connected to the bridge and the proper ratio (A/B) selected, the rheostat dials on the bridge are adjusted to obtain a null balance on the detector. The unknown resistance can then be calculated by multiplying the rheostat setting by the ratio.

Fault-locating bridges are specialized versions of the Wheatstone bridge, designed to locate grounds, crosses, shorts and opens in communication and power circuits. For detailed information on their application, send for Tech. Pub. B5.1130, "Fault Location in Cables" which explains and diagrams methods for locating each of a wide variety of faults.

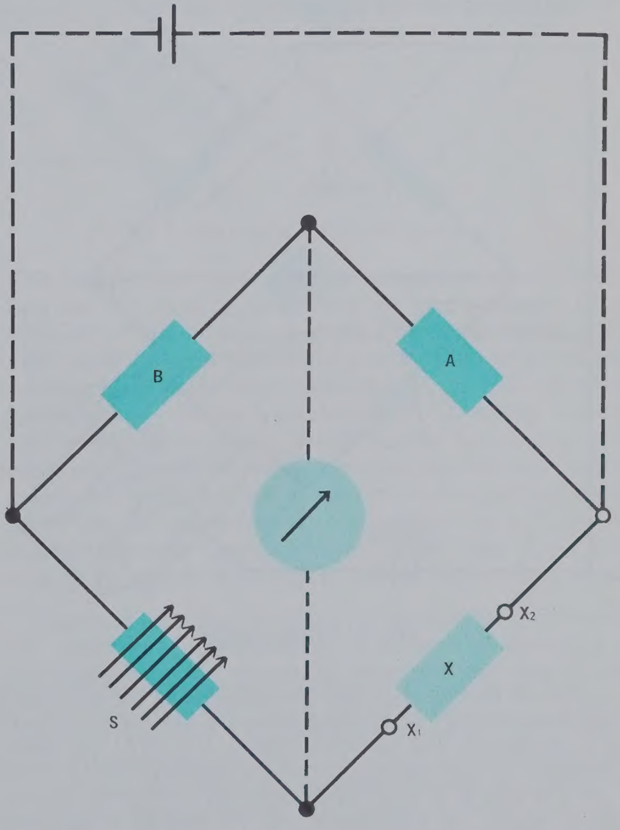


Fig. 1 Wheatstone Bridge

MEASURING TEMPERATURE BY RESISTANCE THERMOMETRY

To measure temperature, bridges are used in conjunction with resistance thermometers, which can be the most accurate of all temperature sensing devices. The materials used in these thermometers (usually platinum, copper, or nickel) exhibit characteristic resistance-versus-temperature relationships over specified temperature ranges. The resistance values obtained are translated into temperature units by referring to appropriate conversion tables or curves.

These resistance values are usually measured by a variation of the Wheatstone bridge; one such variation, designed for the most accurate measurement of resistance-thermometer resistance, is the Mueller bridge. In the ultimate, with extreme care in the arrangement of apparatus, measurements can be made with precision of about 0.0001C.

A typical arrangement for measuring temperature by resistance thermometry is shown in Figure 2.

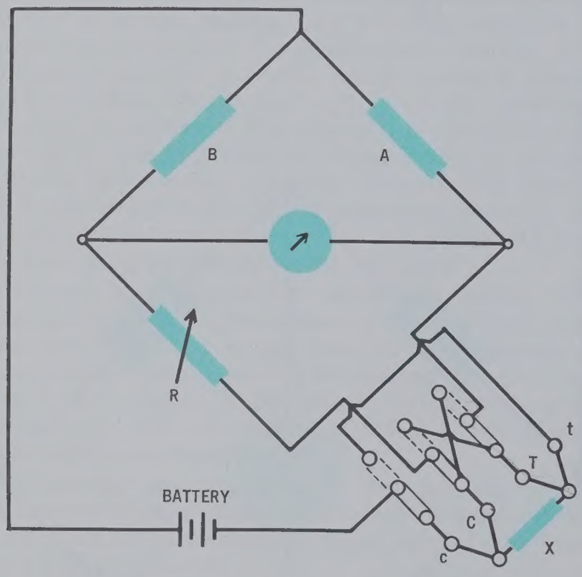


Fig. 2 Mueller Bridge

Two leads and a reversing commutator connect only the thermometer potential leads into the lower arms of the resistance thermometer bridge. The other two leads connect current terminals to the battery circuit. With arms A and B at unity ratio and c as the battery supply lead, measuring-arm resistance (R+lead C) is adjusted to equal thermometer-arm resistance (X + lead T). With the commutator reversed (dotted lines) to make t the battery supply lead, the resistance of R + lead T is balanced against that of X + lead C. Thus, any difference in the resistance of leads T and C increases and decreases the readings by the same amount. As a result, the average of the two readings, after correction for bridge zero, represents thermometer resistance alone.

MEASURING RESISTANCE LESS THAN TEN OHMS

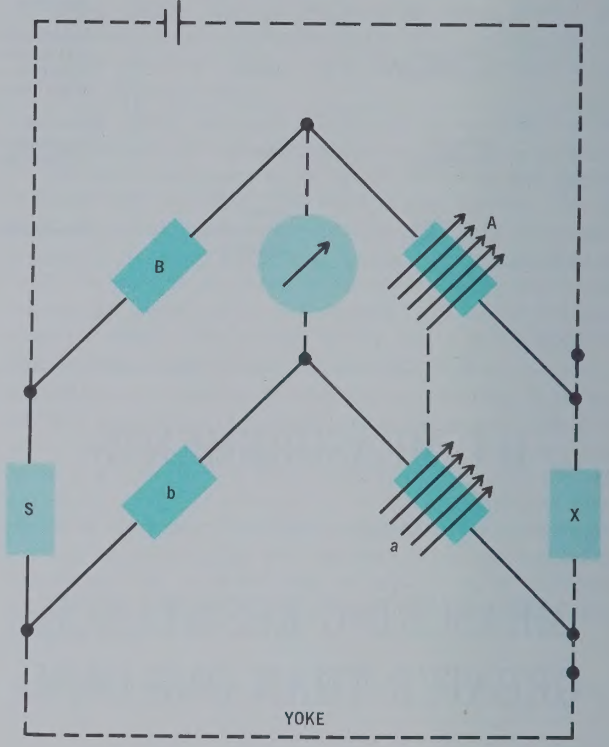


Fig. 3 Kelvin Bridge

Because the resistances of leadwires and contacts can contribute a significant error when measuring extremely low resistance with a Wheatstone bridge, a Kelvin double bridge is recommended for resistances below ten ohms. The Kelvin bridge is a Wheatstone bridge modified to obtain increased accuracy in the measurement of low resistances such as wires, bars, rods, carbon brushes and windings. "Double bridge" refers to a double set of ratio arms which serve to minimize the effect of resistance of leadwires and connectors.

In measuring the resistance of a wire or low-resistance shunt, the unknown resistance is connected to the Kelvin bridge and the adjustable resistors are varied by adjusting the dials on the bridge until the detector (galvanometer or other null detector) reaches a null point.

With the resistances A, B, a and b adjusted so that the ratio A/B is equal to a/b (see Figure 3) and the resistance of the yoke connection held to a minimum value, the unknown resistance is calculated by the equation $X = \frac{A}{B}S$, where X is the unknown resistance, S is the value of the standard resistor and $\frac{A}{B}$ is the ratio multiplier.

For more detailed information on the theory and use of the Kelvin bridge, send for Note Book E-53(1).

A-C MEASUREMENTS

MEASURING CAPACITANCE AND DIELECTRIC LOSS

The 1511 Modified Schering Bridge is designed for measuring the power factor and other dielectric characteristics of insulating materials; the 1513 High-Current Schering Bridge is used for measuring the power factor and capacitance of cables at rated voltage and frequency.

The Modified Schering Bridge circuit, Figure 4, consists of four arms: the high-voltage arms AB and BC and the low-voltage arms AD and CD. In addition, suitable shield and guard arrangements and an adjustable low-voltage source are provided. With the specimen and standard capacitor connected as shown, and with potential applied between point B and ground, the operator balances the bridge. When the bridge is balanced, the potential of point D is so adjusted that the points A and C of the bridge and the shield are all at ground potential.

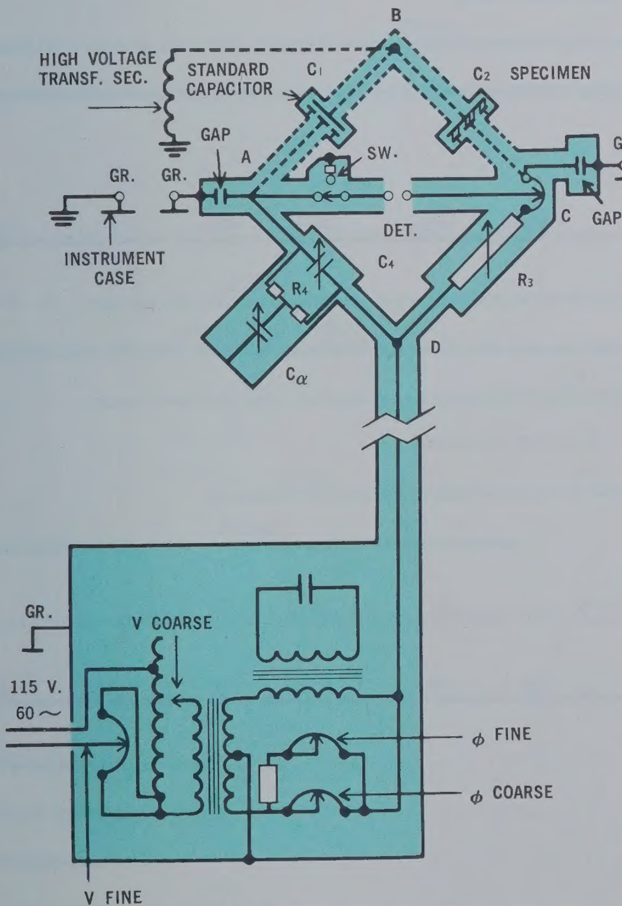


Fig. 4 Modified Schering Bridge

MEASURING ELECTROLYTIC CONDUCTIVITY

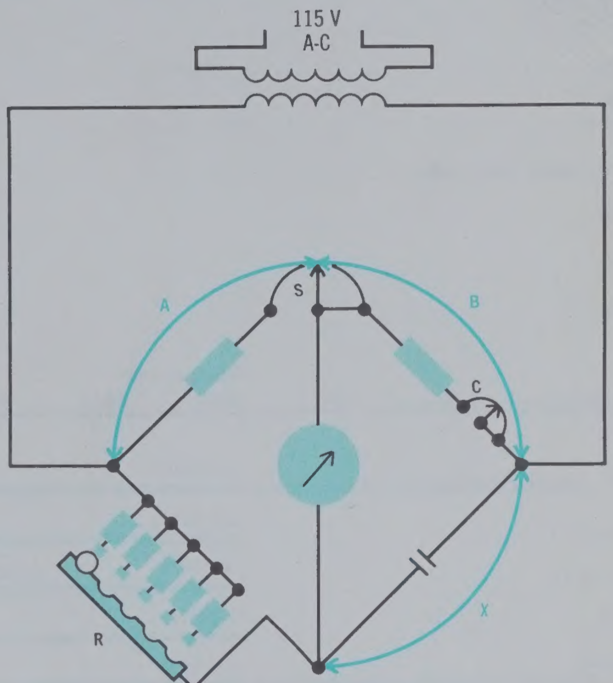


Fig. 5 Electrolytic Conductivity Indicator

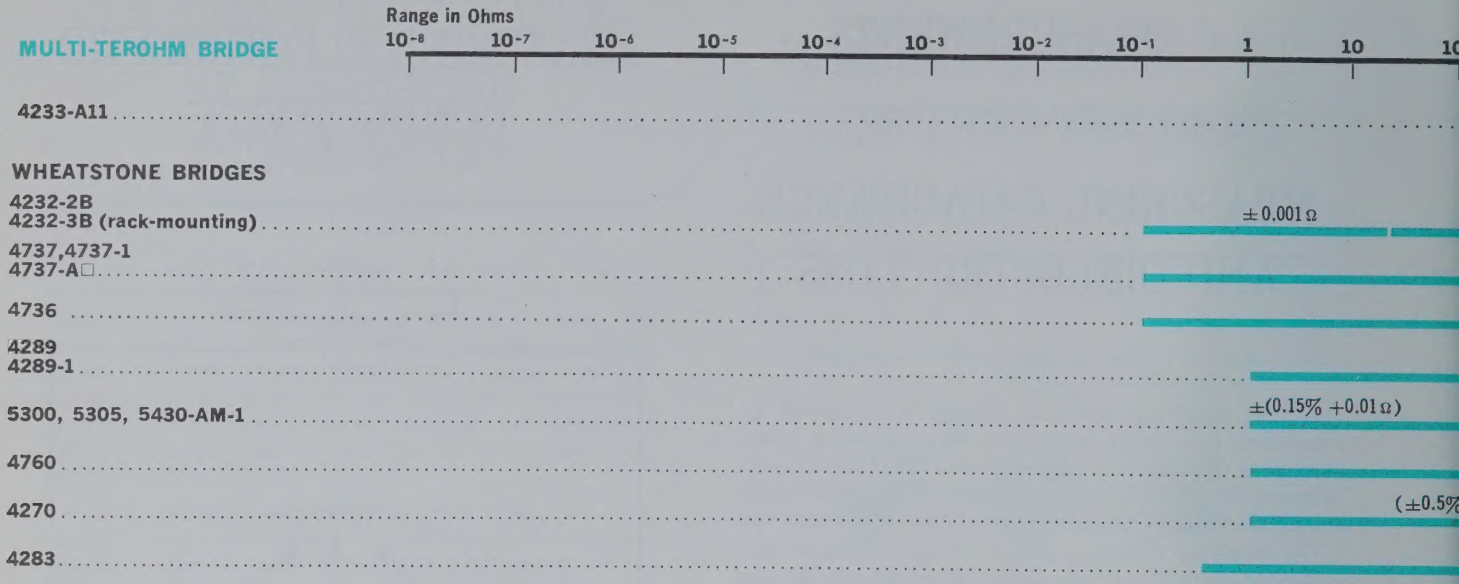
The measurement of electrolytic conductivity of a solution can be used to determine the concentration of a dissolved material when it is the only one present, or to determine the total conductivity of a group of dissolved materials. The standard measurement, called "specific conductance", is the conductance exhibited by a solution when measured by a cell having two electrodes, each one square centimeter in area, spaced one centimeter apart. Such a cell is said to have a cell constant of 1.0 cm^{-1} (one reciprocal centimeter). An a-c circuit is used for such measurements, rather than a d-c circuit, to minimize polarization effects at the electrodes.

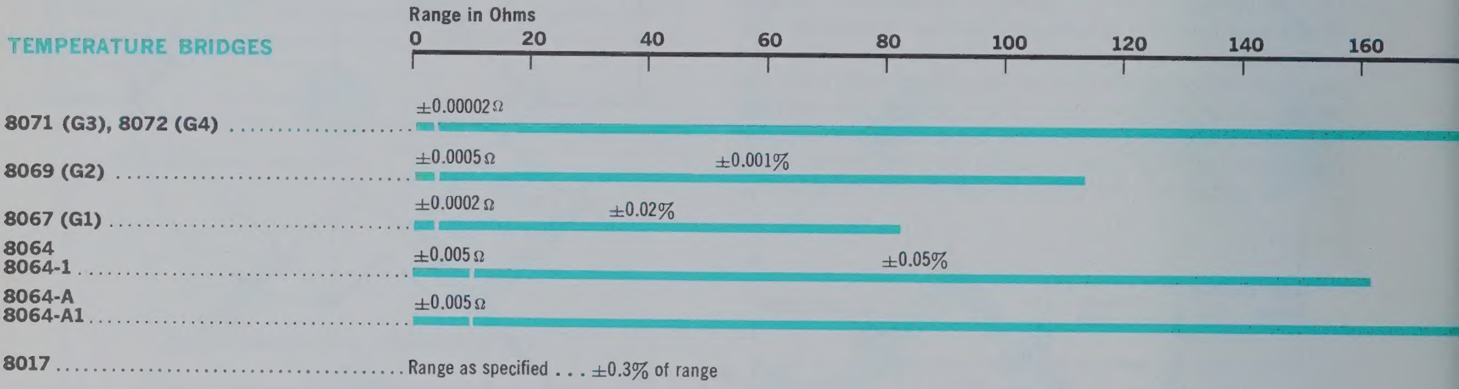
Figure 5 illustrates the circuit schematic of an indicator for electrolytic conductivity. It utilizes a simple a-c Wheatstone-bridge circuit to measure the resistance between the electrodes of a conductivity cell. This resistance is an index of the conductivity of the electrolyte.

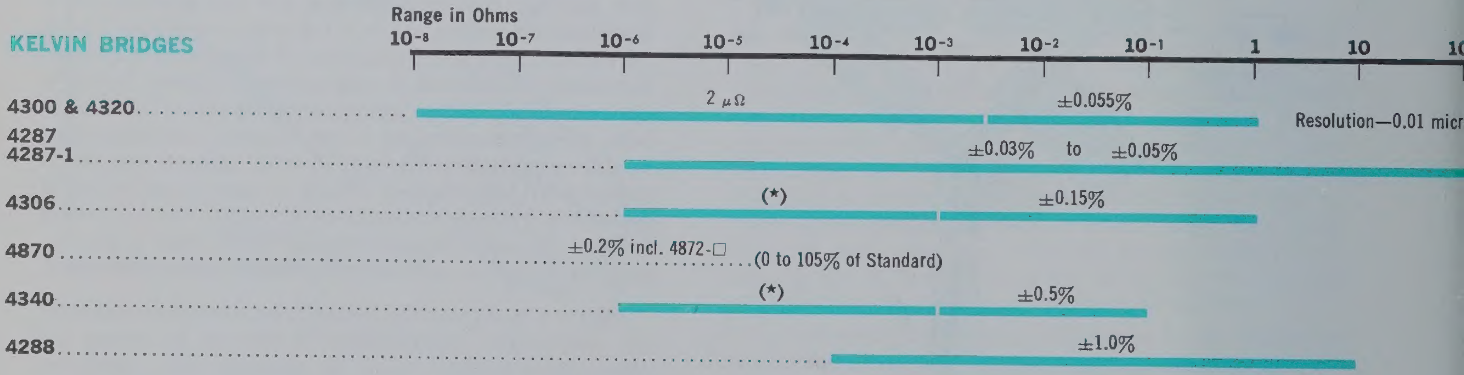
The adjustable resistor C in arm B can be adjusted to compensate both for temperature and for cell-constant variations. Resistance of the standard arm R is chosen by means of a plug switch. With the conductivity cell in arm X and a selected resistor in arm R, the contact of slidewire S is adjusted until the galvanometer indicates bridge balance. The resistances are then in the relation $\frac{A}{B} = \frac{R}{X}$ and the reading of the slidewire scale is multiplied by a factor dependent on the selected value in arm R to obtain the value of X.

SELECTION GUIDE—L&N BRIDGES

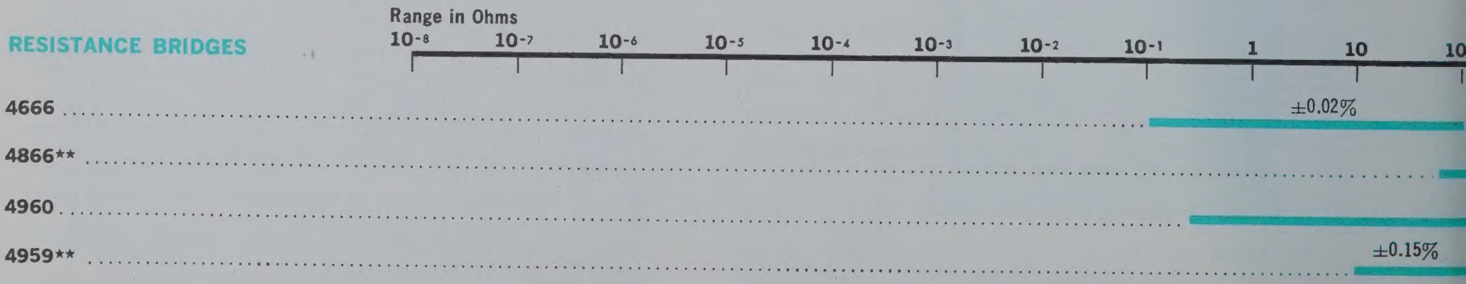
RANGES AND LIMITS OF ERROR . . . D-C BRIDGES *For Resistance and Temperature Measurements*







RANGES AND LIMITS OF ERROR . . . A-C BRIDGES *For Resistance and Conductance Measurements*



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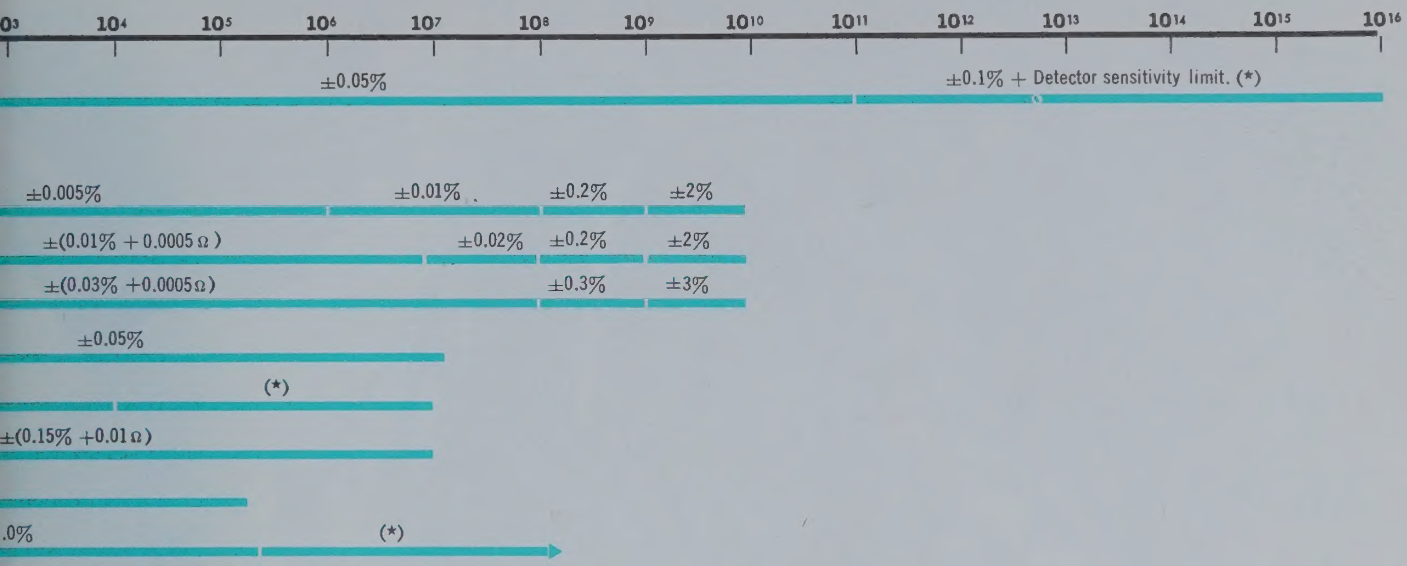
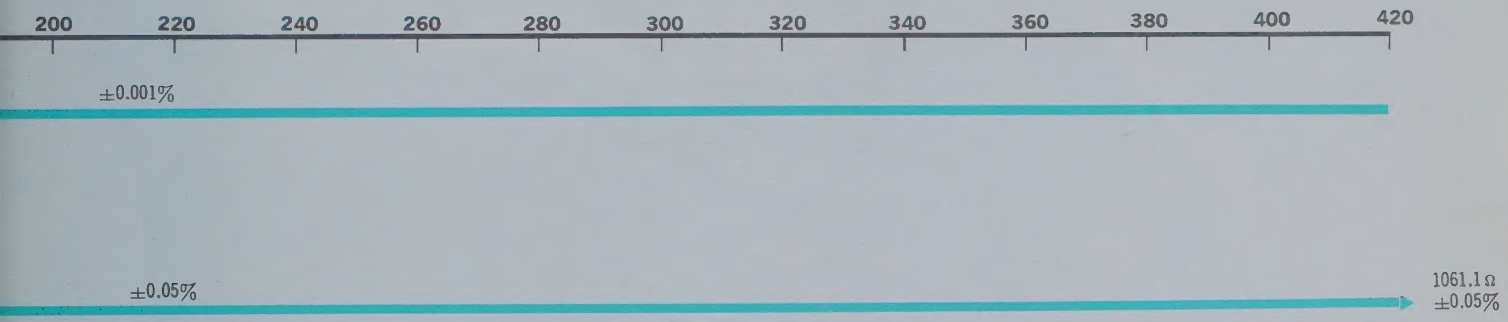
* *To determine limits of error within these range spans, refer to specifications of individual instruments. Unless otherwise specified, all limits of error are in terms of percent of reading.*

** *Also has reciprocal scale for direct reading of measured conductance.*

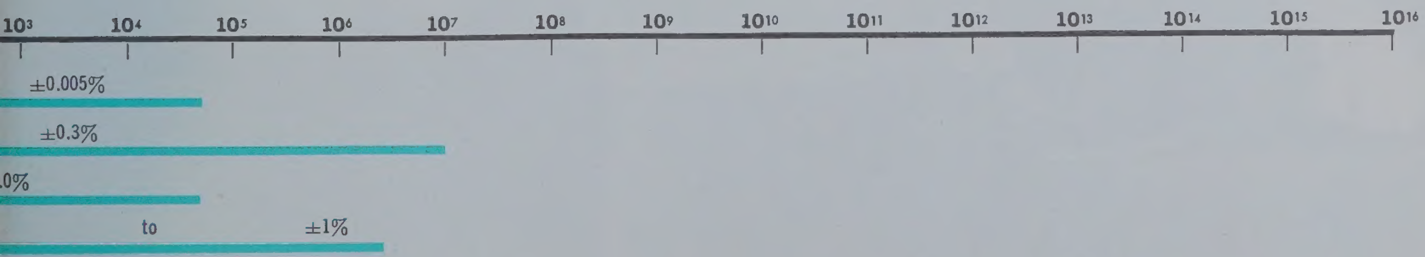
Note: "-1" suffix indicates rack-mounted instrument.





1 vernier division

solution—To 0.01 microhm with internal standards, to 0.0001 microhm with auxiliary standards.



4233-A11 WIDE-RANGE RESISTANCE BRIDGE

FOR MULTI-TEROHM RESISTANCE VALUES TO 10^{16} OHMS WITH HIGH ACCURACY (±0.15% at 10^{12} Ohms)

Unique circuitry

Complete assembly of compatible components

Completely guarded and electrostatically shielded

Designed for ease of calibration

Initially designed for the measurement of semi-conductors in the cryogenic regions, this wide-range bridge has unique circuitry and special features which adapt it to accurate measurements of extremely high resistances. It consists of a multi-terohm bridge, null detector, batteries and other components in a self-contained facility.

Matched, aged resistors of relatively low values (none over 1 megohm) provide inherent accuracy and stability. The bridge is completely guarded to eliminate the effects of leakage on the accuracy of measurements, and all bridge components are electrostatically shielded. In-line digital readout reduces chance of misreading.

The detector is placed across the B-D corners of the bridge, which permits the use of a grounded detector with a grounded sample. This arrangement helps to reduce the pickup problem. The B-OFF-D grounding switch permits grounding of the B or D corners of the bridge. Grounding of the B corner is particularly beneficial when measuring extremely high resistances since the time constant of the bridge is then considerably lower.

Terminals for normal use are located in a covered compartment on the front panel. Suitable terminals are provided at the side of the facility for connecting either a checking standard or an unknown to be measured. The wye-delta high-resistance standards, purchased separately, are used for checking the bridge at nominal resistance of 10^8 to 10^{16} ohms. Each of the three relatively low-valued wye resistors in the standard may be checked separately by the bridge to establish the standard calibration before using it to check the bridge at high values.

SPECIFICATIONS

RANGE—100 ohms to 10^{16} ohms.

BRIDGE RESOLUTION—1 ppm or 0.1 ohm, whichever is greater.

LIMIT OF ERROR—The accuracy is restricted by detector sensitivity and applied voltage when measuring extremely high values of resistance as indicated below. The combined overall limits of error of the facility, including bridge limits and detector sensitivity limits, are:

Ratio Dial Setting	Max. Value of "X"	Max. Overall Limit of Error	Breakdown of Maximum Limit of Error Due to:	
			Bridge	Detector Sensitivity (at 90 volts bridge voltage)
10^{-2}	10^5 Ohms	±0.05%	±0.05%	Negligible
10^{-1}	10^6	±0.05%	±0.05%	Negligible
1	10^7	±0.05%	±0.05%	Negligible
10	10^8	±0.05%	±0.05%	Negligible
10^2	10^9	±0.05%	±0.05%	Negligible
10^3	10^{10}	±0.05%	±0.05%	Negligible
10^4	10^{11}	±0.1%	±0.1%	Negligible
10^5	10^{12}	±0.15%	±0.1%	±0.05%
10^6	10^{13}	±0.6%	±0.1%	±0.5%
10^7	10^{14}	±5.1%	±0.1%	±5%
10^8	10^{15}	±50.1%	±0.1%	±50%
10^9	10^{16}	±500.1%	±0.1%	±500%

RESISTANCE STANDARD ARM—Six decades of 10 x ($10^6 + 10^5 + 10^4 + 10^3 + 10^2 + 10$) ohms.

BRIDGE VOLTAGE—Two 45-volt batteries with center taps. A voltage switch permits selection of bridge voltages of OFF, 0.1, 1, 5, 10, 22.5, 45, 67.5, and 90 volts.

Also available with 1000-V line-operated power supply. Consult factory.

ELECTRONIC NULL DETECTOR—(Boonton Type 56AR-S2)

a. Sensitivity: ±0.2 μV per division at 40 megohms source impedance on most sensitive setting.

b. Input Impedance: 10 megohms on lower sensitivity ranges, over 40 megohms on higher ranges.

c. Noise Level: Less than 1 μV peak to peak.

CABINET — Sloping-front metal console, approx. 22-3/16″ (w) x 27-3/16″ (h) x 18-5/16″ (d); weight approx. 190 lbs.

PRICE— On request.

RECOMMENDED ACCESSORIES

4233-P-☐ Wye-Delta High-Resistance Standards P.O.R.

4233-P1 Adapter Kit; for connecting standard to bridge for internal calibration of standard. P.O.R.

4232-☐B SIX-DIAL HIGH-PRECISION GUARDED WHEATSTONE BRIDGE

A
B
10000
1000
100
10
1
0.1
GUARDED WHEATSTONE BRIDGE
CAT 4232

HIGHLY ACCURATE READOUT TO SIX FIGURES FOR RESISTANCES OF 0.1 OHM TO OVER 11,000 MEGOHMS

Resistors made of grade A manganin wire

L&N type 31 ratio and rheostat switches

Guarded and shielded construction

L&N report of calibration supplied

Easily calibrated without removal from case

May be used as a two- or four-terminal resistance standard, a ratio set, or a limit bridge

L&N 4232 Wheatstone Bridges are designed to satisfy the most demanding applications. Providing high-accuracy six-figure read-out, they are supplied with an L&N Report of Calibration tracing accuracy directly to N B S. These bridges are used in some standardizing laboratories as a primary resistance-measuring instrument; they are employed in making and adjusting very high precision resistors; and they are used by quality assurance groups as the final authority for inspection of purchased components. Every feature that will aid precise measurement has been incorporated into these units, including guarded construction to prevent leakage currents from causing erroneous readings, simple provision for cross-checking of the ratio arm-resistors, aged resistors made of Grade A manganin wire for long-term stability, Type 31-3 Switches constructed to assure lasting reproducibility, in-line read-out and interchangeable bridge-voltage orientation for optimum resolution.

SPECIFICATIONS

LIST NUMBERS—4232-2B (bench top); 4232-3B (rack-mounting).

RANGE—0.1 ohm to 11,111.1 megohms, with setability to 10 ppm or better.

RATIO SELECTION — With two positive-detent rotary switches, ratio setting shown in dual window between switches, 56 combinations available.

RATIO RESISTORS—1, 10, 100, 1000, 1000', 10,000, 10,000' and 100,000 ohms. (Prime (') values provided for cross-check procedure).

RHEOSTAT—Six decades: 10,000, 1000, 100, 10, 1 and 0.1 ohms per step; setting of each selected with positive-detent rotary switch. Setting shown by a number, 0 through 10, in window above each switch.

LIMITS OF ERROR—Limits of Error at time of adjustment* at 25 C with a minimum of 1000 ohms in the rheostat arm:
±0.005% of reading for 20 ohms up to 1.11 megohm
±0.001 ohm for 20 ohms or below
±0.01% above 1.11 megohm to 111 megohms
±0.2% above 111 megohms to 1111 megohms
±2% above 1111 megohms to 11,111 megohms
***Report of Calibration supplied with each instrument.**

(For small differences in resistances or for comparison of precision standards by substitution accuracies down to 1 ppm are achievable.)

STABILITY GUARANTEE—Change in value of individual resistors will not cause bridge readings to vary more than 0.005% throughout the range of 20 ohms to 111 megohms during the first year.

SWITCH CONTACT RESISTANCE—"A" Ratio: Less than 0.001 ohm, stable within 0.0002 ohm.
"B" Ratio and Rheostat: Less than 0.001 ohm per switch, stable within 0.0005 ohm per switch.

CURRENT RATING

Rheostat Arm Used as Resistance Box		Ratio Resistors	
Decade ohms	Amperes	Ohms	Amperes
10,000	0.003	100,000	0.0016
1000	0.010	10,000	0.005
100	0.035	1000	0.016
10	0.11	100	0.05
1	0.5	10	0.16
0.1	1.6	1	0.5

APPLIED VOLTAGE—With potential across A-C bridge corners:
Up to 10 volts on lowest range, up to 100 volts on highest range, as listed on ORIENTATION card.
With potential across B-D bridge corners:
Up to 5 volts on lowest range, up to 32 volts on upper ranges, as listed on ORIENTATION card. Exception: up to 63 volts when measuring between 10K and 100K ohms.

DETECTOR KEYS—Three low-thermal spring-return pushbuttons for choice of detector sensitivity.

POWER SUPPLY KEYS—Two spring-return pushbuttons; ON and REVERSE. Both lockable.

TERMINALS—Front: four. Sloping Rear Panel: twelve. A ground terminal is also provided.

DATA CERTIFICATE—L&N Report of Calibration supplied with each instrument. This Report is based on standards maintained by L&N and certified at intervals by N B S.

CASE—Metal, gray finish; 19″ (w) x 10½″ (h) x 9½″ (d) (8⅜″ behind panel); weight approx. 30 lb.

PRICE—4232-3B: $2040.00; 4232-2B: $2090.00.

RECOMMENDED ACCESSORIES

2430-e Galvanometer
9834 Null Detector
9834-1 Null Detector (rack-mounting)
9876 Power Supply
9876-1 Power Supply (rack-mounting)

A
B
LEEDS & NORTHRUP
4232 GUARDED WHEATSTONE BRIDGE

4232-A□-B WHEATSTONE BRIDGE FACILITY

Complete assembly of compatible components

Ready to plug in and use—set-up time eliminated

D-c power supply—dial any voltage 0 to 100

D-c null detector—fast response, short period

LEEDS & NORTHRUP / WHEATSTONE BRIDGE FACILITY
GUARDED WHEATSTONE BRIDGE

These complete d-c measurement facilities provide selected mutually-compatible components in a compact, table-top cabinet.

The 4232-A12-B General-Purpose Facility comprises a 4232-3B Guarded Wheatstone Bridge, a 9834-1 Guarded D-C Null Detector, and a 9877-1 Guarded D-C Power Supply and cabling. The lower-cost 4232-A11-B Facility is recommended when most measurements will be 100,000 ohms or less and differs only in the use of a 9876-1 unguarded D-C Power Supply.

SPECIFICATIONS

CABINET—Sloping-front metal console finished in light-gray baked enamel, with lifting handles and vinyl dust cover; 22-3/16″ (w) x 27-3/16″ (h) x 18-5/16″ (d at bottom); weight approx. 117 lb.

PRICE—4232-A11-B: $2960.00; 4232-A12-B: $3100.00.

4737 GUARDED WHEATSTONE BRIDGE

LEEDS & NORTHRUP
4737-A20 GUARDED WHEATSTONE BRIDGE
DETECTOR POWER SUPPLY

FOR MEASUREMENTS FROM 0.1 OHM TO 11,111 MEGOHMS WITH LABORATORY PRECISION

Advanced circuit design

Completely guarded and shielded

Designed for ease of calibration

Automatic voltage selection prevents overheating

Available as complete facility (bench-top, rack or console) as well as bench-top or rack-mounting bridge

L&N report of calibration available

Available in a choice of five models, the new 4737 Guarded Wheatstone Bridge is the ideal instrument for two-terminal resistance measurements from 0.1 ohm to 11,111 megohms when laboratory precision is required. These bridges are particularly useful in calibrating resistors on a production-line basis, performing critical laboratory experiments or making routine resistance measurements. Detector meter on the -A20 and -A21 models can be calibrated in either percent or ohm-deviation, by use of the continuously-adjustable sensitivity control, to establish Go/No-Go limits for repetitive checking. Two terminals at the front of the instrument provide connections for using the six-decades of the rheostat arm as a high-accuracy resistance box.

The 4737-A20 bench-top and 4737-A21 rack-mounting models are complete facilities consisting of a six-decade Wheatstone bridge, 0.5-microvolt sensitivity null detector and guarded power supply. Both models provide everything needed for high-accuracy resistance measurements in one compact case—completely factory-wired and tested.

These bridges utilize a new solid-state MOS-FET detector, providing low-noise, stable zero and sensitivity of 0.5 μV per division. The range switch automatically selects the proper voltage for each range when using the internal power supply. Rear terminals are provided for use with an external power supply or detector when desired for unusual applications. Bridges are completely guarded and shielded. Critical resistors of 100 ohms and greater are constructed of Evanohm wire, those below 100 ohms use manganin wire; new silver-alloy rheostat decade switches feature low contact resistance. The instrument may be completely calibrated without removing from the case. Readout is a series of in-line windows. An L&N Report of Calibration is available (add suffix "-B").

The 4737 bench-top and 4737-1 for relay-rack mounting provide the same high-quality bridge, but utilize an external detector and power supply. The 4737-A12 Facility consists of the 4737-1 Wheatstone Bridge, an adjustable 9876-1 Power Supply and a 9834-1 Null Detector with 0.1-μV sensitivity. This model is especially useful when the voltage across the unknown resistor must be adjusted to a specific value and when maximum bridge sensitivity for measurements above 10 megohms is desired.

SPECIFICATIONS

LIST NUMBER—4737 Bench-Type; 4737-1 for 19″ Relay Rack; 4737-A20 Bench-Type Facility; 4737-A21 19″ Rack-Type Facility; 4737-A12 Large Console-Type Facility using 4737-1, 9876-1 Power Supply and 9834-1 Null Detector.

RANGE—0.1 ohm to 11,111 megohms.

LIMIT OF ERROR—±(0.01% + 0.0005 ohm) up to 10 megohms, ±0.02% from 10 megohms to 100 megohms, ±0.2% from 100 megohms to 1000 megohms, and ±2% above 1000 megohms.

WITH L&N REPORT OF CALIBRATION—Report is based on standards maintained by L&N and certified at intervals by the NBS. The following data are given at 25 C:

Ratio: Multiplying factors are tabulated; factors given are correct within 30 ppm except 10^{-1} (0.05%), 10^7 (0.01%), 10^8 (0.1%) and 10^9 (1%).

Rheostat: Measured values for each position of the 1000, 100, 10, 1, 0.1, and 0.01 dials are given. Values are correct within 20 ppm or 0.005 ohm, whichever is greater.

RHEOSTAT SWITCHES—Six decades in steps of 10 x (1000 + 100 + 10 + 1 + 0.1 + 0.01) ohms.

BINDING POSTS—(4737 and 4737-1 only) Nine. On top plate, guard, ground and two for unknown resistance. On back plate: two for detector, two for power supply, and one for ground.

(4737-A20 and 4737-A21 only) Ten. On top plate, guard, ground, two for unknown resistance. On back plate, three for internal-external null detector feature and three for internal-external power supply feature.

CALIBRATION POINTS—Five Teflon feed-through terminals on rear terminal plate provide accessible current and potential points for calibration purposes.

MULTIPLIER DIAL—Eleven-position switch from 10^{-1} to 10^9. Ratio resistors vary from 0.01 ohm to 10 K, with 10 K always in at least one bridge ratio arm.

CURRENT RATING—Of rheostat arm used as resistance box, determined by highest decade in use; for 0.01 ohm, 3.5 A; for 0.1 ohm, 1.1 A; for 1 ohm, 0.35 A; for 10 ohm, 0.11 A; for 100 ohm, 0.035 A; for 1000 ohm, 0.011 A.

KEYS—Three; detector on-off, power supply on-off, and power supply normal-reverse.

GUARDED CIRCUITS—(4737 and 4737-1 only) X1 binding post, null detector key, and multiplier switch. (4737-A20 and -A21 only) X1 binding post, power supply, power-supply terminals, power-supply keys, and multiplier switch.

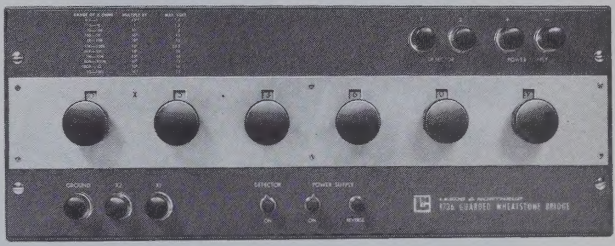
CASE—4737: 19¼″ x 11″ x 9½″, 24 lb; 4737-1: 19″ x 10-7/16″ x 8⅜″, 15 lb; 4737-A12: 22-3/16″ x 27-3/16″ x 18-5/16″, 110 lb; 4737-A20: 19¼″ x 11″ x 9½″, 29 lb; 4737-A21: 19″ x 10-7/16″ x 8⅜″, 20 lb.

PRICE—4737: $800.00; 4737-1: $800.00; 4737-A12: $1900.00; 4737-A20: $1150.00; 4737-A21: $1150.00; "-B", add $350.00.

RECOMMENDED ACCESSORIES
(for 4737, 4737-1 and 4736)

127272 Mounting Brackets
Std 2233-9 22.5-V and Std 2233-1 1½-V dry cell, or
9876 Line-operated D-C Power Supply
9834 Guarded D-C Electronic Null Detector, or
2430-e Type E Galvanometer
037200 Galvanometer Cable

4736 GUARDED WHEATSTONE BRIDGE



MEASUREMENTS TO 11,111 MEGOHMS WITH HIGH ACCURACY

Designed to replace the 4735 Bridge, this new Wheatstone bridge is mounted in a smaller, more compact case. The bridge features an expanded range (up to 11,111 megohms) and decade switches of a new, improved design. Provision is made for using the rheostat decades as an adjustable resistance box. All readings plus the range-multiplier are displayed in a series of in-line windows for ease of readout and operation.

SPECIFICATIONS

LIST NUMBERS—4736 Bench-type; 4736-1 Rack-type.

RANGE—0.1 ohm to 11,111 megohms.

LIMIT OF ERROR—±(0.03% +0.0005 ohm) up to 100 megohms, ±0.3% from 100 megohms to 1,000 megohms, and ±3% above 1,000 megohms.

RHEOSTAT SWITCHES—Five decades in steps of 10 x (1000 + 100 + 10 + 1 + 0.1).

MULTIPLIER DIAL—Eleven-position switch from 10^{-1} to 10^9. Ratio resistors vary from 0.01 ohms to 10 K, with 10 K always in at least one bridge arm.

MAXIMUM APPLIED VOLTAGE—Based on rheostat arm set at 1,000 (1000 ohms) minimum:

Resistance Range (Ohms)	Multiplier	Maximum Voltage	Resistance Range (Ohms)	Multiplier	Maximum Voltage
0.1 to 1	10^{-1}	1.5	100 K to 1 M	10^5	15
1 to 10	1	1.5	1 M to 10 M	10^6	15
10 to 100	10	5	10 M to 100 M	10^7	15
100 to 1 K	10^2	15	100 M to 1 G	10^8	15
1 K to 10 K	10^3	50	1 G to 10 G	10^9	15
10 K to 100 K	10^4	22.5			

CURRENT RATING—Of rheostat arm used as resistance box, determined by highest decade in use; for 0.1 ohm, 1.1 A; for 1 ohm, 0.35 A; for 10 ohm, 0.11 A; for 100 ohm, 0.035 A; for 1000 ohm, 0.011 A.

KEYS—Three: detector on-off, power supply on-off, and power supply normal-reverse.

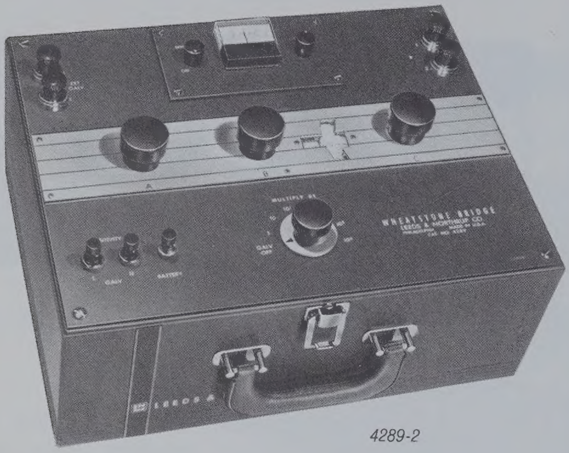
BINDING POSTS—Seven: ground and two for unknown resistor; two for power supply, and two for null detector.

GUARDED CIRCUITS—X1 binding post, detector 2 post, null-detector key, and multiplier switch.

CASE—4736: 19″ x 7″ x 5-9/16″, 12 lb.; 4736-1: 19″ x 7″ x 6-9/16″, 12 lb.

PRICE—$650.00; suffix "-B", add $300.00.

4289 and 4289-2 PRECISION D-C WHEATSTONE BRIDGE


4289-2

FOR MEASUREMENTS FROM 1 OHM
TO 11.01 MEGOHMS WITH
LABORATORY ACCURACY

Direct-reading—single row of digits plus scale reading

Self-contained with light-beam galvanometer or null detector

Designed to meet the need for a moderately-priced, self-contained, precision Wheatstone bridge, these high-quality instruments combine laboratory accuracy with the convenience of portability. They are used in field and laboratory for many types of on-the-spot calibrations and production testing of resistors and resistance devices such as meters, instruments, motor and transformer windings, and components of electronics communication, refrigeration and heating equipment. Completely self-contained with light-beam galvanometer or null detector, batteries and central readout, the bridge is simply connected to the unknown. An L&N Report of Calibration is available (add suffix "-B").

SPECIFICATIONS

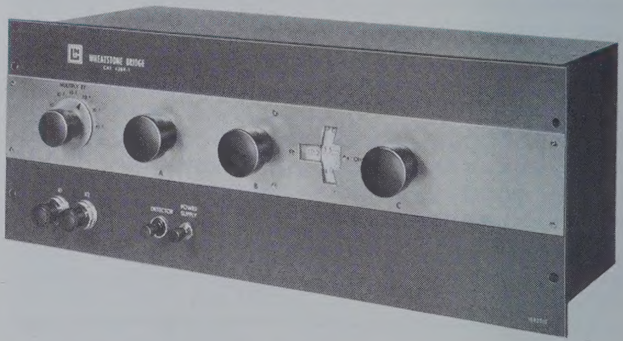
LIST NUMBERS—4289 (Galvanometer); 4289-2 (Null detector).

4289-1 PANEL-MOUNTED PRECISION D-C WHEATSTONE BRIDGE

FOR MEASUREMENTS FROM 1 OHM
TO 11.01 MEGOHMS WITH
LABORATORY ACCURACY

Direct-reading—single row of digits plus scale reading

Designed for mounting in standard 19" panel



For precise measurement of resistance, these d-c bridges feature panel-mounted design for assembly in production bench or research instrumentation installations. These precision bridges are ideal for many diverse resistance measurements in the laboratory or factory. With a suitable detector they can be used to monitor changes and variations in resistance; with a recorder and a deviation amplifier they can provide precision control of numerous functions; on the production line they can provide a reference for repetitive checking of resistive elements such as heater windings. An L&N Report of Calibration is available (add suffix "-B").

RATIO ARMS—Seven ratios, switch-selected; 1:100; 1:10, 1:1; 10:1; 100:1; 1000:1; 10,000:1.

RANGE—1 ohm to 11.01 megohms in seven ranges.

RHEOSTATS—100 ohms-per-step decade and 10 ohms-per-step decade—plus a slidewire shunted to 11 ohms.

LIMITS OF ERROR—±0.05% of reading. Improves to ±0.03% as "A" dial is switched from the 1 to 10 position.
With L&N Report of Calibration: ±0.02%.

GALVANOMETER (4289)—Built-in, light-beam; sensitivity 0.01% or better up to 0.5 megohm, ±0.025% to ±0.045% at one megohm, dependent on dial settings.

NULL DETECTOR (4289-2)—Built-in, electronic; sensitivity better than 0.005% when measuring 1 ohm, better than 0.001% from 10 to 100K ohms, better than 0.015% from 1 to 10 megohms.

KEYS—Two for low and high sensitivity selection and one for battery.

BINDING POSTS—Four, two for connection to unknown resistance, and two for detector, if required.

BATTERIES—Three; One 22½-volt for measuring circuit. Two 1½-volt for galvanometer lamp (4289); two 6-volt for detector (4289-2).

CASE—Metal case with handle and slip-hinged removable lid; 14¼" x 11½" x 7½"; weight about 21 lb.

PRICE—4289: $625.00; 4289-2: $700.00; "-B", add $250.00.

OPTIONAL ACCESSORIES

099007 Line-operated Lamp Power Supply (4289), Price $33.00.

099055 Line-operated Power Supply (4289-2), Price $38.00.

SPECIFICATIONS

RANGE—1 ohm to 11.01 megohms in seven ranges.

RATIO ARMS—Seven ratios, switch-selected; 1:100; 1:10, 1:1; 10:1; 100:1; 1000:1; 10,000:1.

RHEOSTATS—100 ohms-per-step decade and 10 ohms-per-step decade—plus a slidewire shunted to 11 ohms.

LIMITS OF ERROR—±0.05% of reading. Improves to ±0.03% as "A" dial is switched from the 1 to 10 position.
With L&N Report of Calibration: ±0.02%.

DETECTOR—Not supplied; rear detector terminals for external null detector.

KEYS—One lock-down detector key, and one lock-down battery key.

INPUT—Front and rear terminal posts for "unknown".

POWER SUPPLY—One 3-volt battery. Maximum drain on battery is 15 mA, giving estimated life of 1-year normal service.

CASE—Metal, gray enamel finish; 19" panel width x 6-31/32" (h) x 7" (d); weight about 15 lb.

PRICE—$520.00. "-B" add $250.00.

RECOMMENDED ACCESSORIES

9834-1 Null Detector, or

2437-1-☐ ☐ Null Detector

5300 & 5305 TYPE S TEST SETS

FOR ROUTINE RESISTANCE TESTING FROM 1 TO 9,999,000 OHMS

Provision for external batteries and galvanometer

Rugged construction for portable use

5300 has provisions for Murray and Varley loop tests

The Type S-1 and S-2 (illustrated) Test Sets are small portable Wheatstone bridges designed primarily for ordinary resistance testing. Completely self-contained and reduced to essentials for easy operation, these sets are used extensively in the communications and electric power industries. The two models are identical with the exception that the Type S-1 also has provisions for locating grounds and crosses by the Murray and Varley Loop Tests.

SPECIFICATIONS

LIST NUMBERS—5300 (Type S-1); 5305 (Type S-2).

RANGE—1 to 9,999,000 ohms, sensitivity adequate from 1 to 40,000 ohms with internal battery and galvanometer.

RATIO ARMS—Enclosed dial switch having seven multiplying values: 0.001, 0.01, 0.1, 1, 10, 100 and 1000.

RHEOSTAT—Four decades 9 (1 + 10 + 100 + 1000) ohms. Enclosed dial switches.

LIMITS OF ERROR—Overall bridge error: ±(0.15% + 0.01 ohm). Of ratio, ±0.05%; in rheostat arm, resistance change from zero setting of dials equals dial setting ±(0.1% + 0.01 ohm).

GALVANOMETER—Built-in, pointer type; sensitivity, 1 μA per scale division.

BATTERY — Contained in case (4.5 V—three type "D" flashlight batteries).

KEYS—For galvanometer and battery.

CASE—Oak, with hinged lid and carrying strap; 9½" x 8½" x 6⅛"; weight approx. 10 lb.

PRICE—5300: $275.00; 5305: $230.00.

RECOMMENDED ACCESSORY

5431 Leather Carrying Case. Price $37.50.

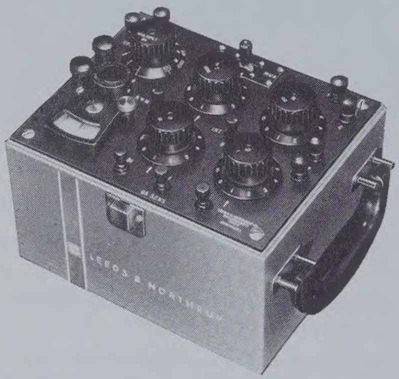
5430-AM-1 TYPE U TEST SET

FOR LOCATING LINE AND CABLE FAULTS IN SIGNAL COMMUNICATION CIRCUITS

Enclosed-dial ratio and rheostat switches with knurled knobs for easy manipulation

May be used as a four-dial adjustable resistance

Provision for Murray, Varley and Hilborn loop tests



The Type U Test Set was designed to meet the need for a portable Wheatstone bridge capable of identifying faulty wires in a cable, locating grounds, shorts and crosses by the Murray, Varley, Hilborn, and other loop tests, locating opens by capacitance methods and measuring conductor resistances. Ruggedly constructed, this bridge features dials which can be manipulated by linemen wearing gloves, slip-hinge removable lid for operation in close quarters, and convenient binding posts for bench use with external galvanometer and batteries.

SPECIFICATIONS

RATIO ARMS—Enclosed dial switch. Multiplying values of 1/1000, 1/100, 1/10, 1/9, 1/4, 1/1, 10/1, 100/1 for resistance measurements and for Varley loop tests. Also settings of M1000, M100 and M10 for ratios in Murray loop tests.

RHEOSTAT—Enclosed dial switches. Four decades, 10 (1 + 10 + 100) + 9 x 1000 ohms + infinity.

LIMITS OF ERROR—Overall accuracy: ±(0.15% + 0.01 ohm).

GALVANOMETER—Pointer-type. Sensitivity: one μA per scale division.

BATTERIES—(3) Size "D" batteries, housed in separate leakproof compartment with molded-in terminals.

KEYS—Galvanometer sensitivity and battery.

CASE—Metal, with plastic carrying handle and removable lid; 8⅜" x 6⅞" x 6⅜"; weight approx. 8¾ lbs.

PRICE—$280.00.

RECOMMENDED ACCESSORIES

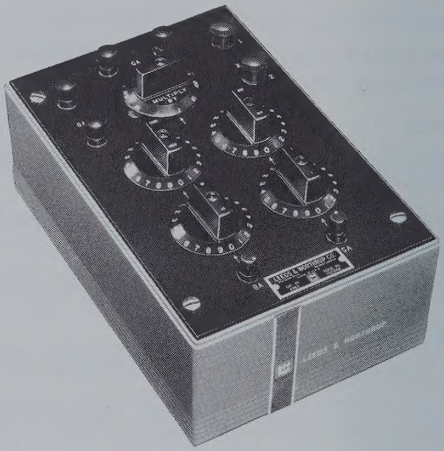
5431-M-1 Carrying Case, Price $37.50.
Std 986 Battery (3)
5412 Buzzer, Price $75.00.
9872 Telephone Receiver, Price $10.50.
2340-c Galvanometer, or
2435-c Galvanometer

4760 D-C WHEATSTONE BRIDGE

FOR RESISTANCE MEASUREMENTS OF MODERATE ACCURACY FROM 1 OHM TO 9.999 MEGOHMS

Enclosed rheostat switches

Rheostat decades may be used as adjustable resistance



For measurements requiring moderate precision, the 4760 Wheatstone Bridge is suitable for d-c resistance measurements in routine work such as the adjustment of special-value wire-wound resistors by resistor manufacturers and in educational institutions where student assembly of accessories is desired. Designed for simplicity of operation, all components are clearly marked, and switching positions are duplicated on the decade dials so that desired resistance can be obtained in minimum time. The rheostat arm may be used independently as a four-dial decade resistance box. Enclosed dial switches protect the contacts from contamination.

SPECIFICATIONS

RANGE—1 ohm to 9.999 megohms.

RATIO ARMS—Seven multiplying values: 0.001, 0.01, 0.1, 1, 10, 100 and 1000.

RHEOSTAT—Range 0 to 9999 ohms in steps of 1 ohm; four decades, 9 (1 + 10 + 100 + 1000) ohms.

LIMITS OF ERROR—Overall bridge error: ±(0.15% + 0.01 ohm).

KEYS—For galvanometer and battery.

CASE—Gray metal; 9⅝" x 6⅜" x 5⅛"; weight, 5½ lbs.

PRICE—$260.00.

RECOMMENDED ACCESSORIES

2340-c Galvanometer, or
2435-c Galvanometer
Std 2233 Battery

4270 PERCENT LIMIT D-C WHEATSTONE BRIDGE

FOR ROUTINE TESTING WITHIN A PERCENT LIMIT RANGE

Fast, accurate inspection of resistors using production part as standard

Readily visible pointer galvanometer

The 4270 Percent Limit Bridge is a simple, rapid, economical tool for routinely inspecting the resistance of elements used in radios, heaters, telephone equipment and other electrical devices. Inspection is made by comparing the unknown resistance with a resistance of the same nominal value, accepted as standard. Most users of this instrument make a simple jig for connecting resistors to the bridge. For a standard, they normally use a measured production unit. The bridge contains a built-in galvanometer, and with the connection of standard, battery and jig, the setup is complete.

SPECIFICATIONS

RANGE—0 to ±15%.

RATIO ARMS—Adjustable slidewires, with scale reading in per cent deviation from comparison standard (15 scale divisions).

STANDARD ARM—Uses external standard resistor—from 1 to about 250,000 ohms—for comparison.

LIMIT OF ERROR—±0.5% (½ scale division).

GALVANOMETER—Built-in, pointer type; sensitivity, 1 μA per scale division.

KEYS—For galvanometer and battery.

CASE—Gray metal; 8½″ x 6¼″ x 5″; weight about 6 lb.

PRICE—$230.00.

RECOMMENDED ACCESSORY

Std 2233 Battery

4283 COMPACT D-C WHEATSTONE BRIDGE

FOR ROUTINE MEASUREMENTS FROM 0.3 TO 300,000 OHMS

Direct-reading slidewire scale

Pointer-type galvanometer

This low-cost, compact portable bridge is designed for routine resistance testing in measuring values in electronic, communication and electrical instruments where greater accuracy is required than is obtainable with a multimeter. Completely self-contained, the bridge has an extra pair of binding posts for connecting external reference standards when making routine comparisons of similar resistances, as well as internal terminals for optional connection to an auxiliary power supply.

SPECIFICATIONS

RANGE—0 to infinity in 6 ranges.

RATIO ARMS—Adjustable slidewire calibrated 0 to infinity.

STANDARD ARM—Selector switch and six standard resistors of 1, 10, 100, 1000, 10,000 and 100,000 ohms.

LIMITS OF ERROR—±1.0% of reading for unknown resistances between 0.3 and 300,000 ohms.

GALVANOMETER—Built-in, pointer-type; sensitivity sufficient to detect a 1% change or better when measuring resistances from 0.3 to 300,000 ohms.

KEYS—One galvanometer, one battery.

BATTERIES—Two 1½-V batteries, series-connected.

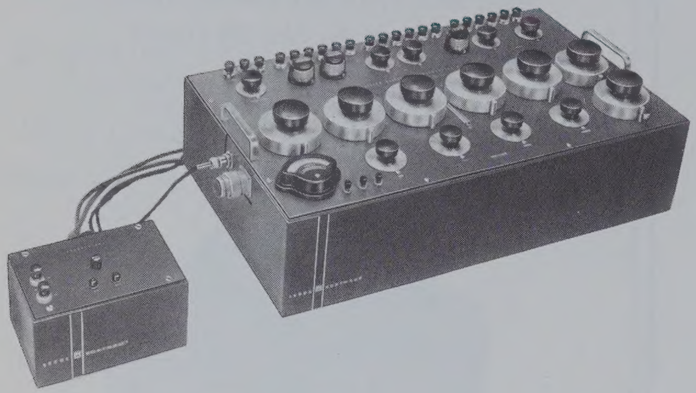
CASE—Metal case with handle: 7¾″ x 6⅛″ x 5⅞″; weight approx. 4½ lb.

PRICE—$250.00.

OPTIONAL ACCESSORY

039733 Leather Carrying Case, Price $37.25.

8072-B TYPE G-4 MUELLER BRIDGE



FOR THE HIGHEST COMMERCIALLY AVAILABLE PRECISION FOR RESISTANCE THERMOMETER MEASUREMENTS OF 0 TO 422.11111 OHMS IN STEPS OF 1 MICROHM

Constant-temperature chamber with separate thermostatic control unit for critical resistors

Commutator for four-lead resistance thermometer

Milliammeter indicates current in thermometer

Mercury switches provided for higher-resistance decades and commutator

L&N report of calibration supplied with bridge

The L&N G-4 is a high-accuracy d-c Mueller bridge with the highest commercially available precision for making laboratory temperature measurements of primary platinum resistance thermometers. It can be used with standard or special three- or four-lead resistance thermometers. The bridge resolution of 1 microhm is generally equivalent to 10 microdegrees C. When functioning as a temperature bridge, the initial measurement of R_0 prior to measuring R_t substantially eliminates the residual bridge error. It is this characteristic which makes the bridge resolution meaningful in making temperature measurements of the highest precision.

The G-4 has provision for using the rheostat arms as a four-terminal standard when checking or certifying other Mueller bridges. Highest-stability resistors are enclosed in a thermostatically-controlled constant-temperature chamber consisting of a separate thermostatic control unit, and a cork-lined aluminum case to provide complete electrostatic and thermal shielding. Mercury switches are provided for higher resistance decades and commutator. This bridge can supply the critical dial settings to an external readout or printing device, when desired. An L&N Report of Calibration is furnished with each G-4 Bridge.

SPECIFICATIONS

RANGE—0 to 422.11111 ohms in steps of 0.000 001 ohm.

RATIO ARMS—Each arm is 500 ohms. A ten-turn, infinite resolution potentiometer at the apex of the arms adjusts the ratio arms accurately for unity ratio.

RHEOSTAT ARM—Five Waidner-Wolff (series-parallel) decades of 10 x (0.000001) ohm, 10 x (0.00001) ohm, 10 x (0.0001) ohm, 10 x (0.001) ohm, 10 x (0.01 ohm). Two decades at the end of the ratio arms of 10 x (0.1) ohm and 10 x (1) ohm. A 10 x (10) ohm decade and four-position 100 ohms-per-step switch. Rheostat arm may be used as a four-terminal, high-precision, adjustable resistor.

LIMITS OF ERROR*—±0.001% or 5 microhms, whichever is larger, using L&N Report of Calibration corrections.

CONSTANT TEMPERATURE CHAMBER—Insulated chamber with a thermostatically-controlled heater maintains the critical bridge resistors at a temperature of about 35 C to a stability of ±0.01 C.

GALVANOMETER DAMPING CIRCUIT—Circuit provided with adjustable resistors for either series or parallel galvanometer damping.

BRIDGE CURRENT REGULATOR—Three keys provided to select different bridge currents. Two of these currents are adjustable by means of individual rheostats.

MILLIAMMETER—Four switch-selected ranges provided. Two ranges, 0-2.5 and 0-10 mA, indicate thermometer current. Other two ranges, 0-5 and 0-20 mA, indicate rheostat-arm current when arm is used as precision four-terminal resistor.

REPORT OF CALIBRATION—L&N Report of Calibration provides initial calibration data. Subsequent calibrations performed by the user, in accordance with directions supplied with the instrument, are simply checked with an 8070-B Calibrating Resistor.

CASE—Aluminum case and top plate, case lined with cork, protective lid; 28½" x 16¼" x 10¾"; weight approx. 70 lb.

THERMOSTATIC CONTROL UNIT—Separate unit, supplied with bridge. For description, see Type G-3 Mueller Bridge.

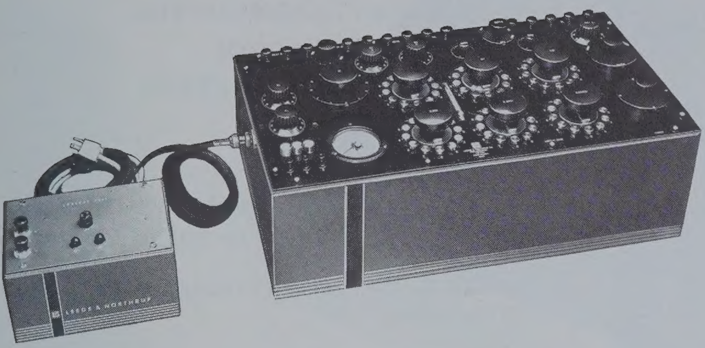
PRICE—(Including Report of Calibration) on request.

**When measuring absolute resistance.*

RECOMMENDED ACCESSORIES

2285-b Galvanometer and 2100 Reading Device or
9834 Detector or
9838 Detector
Std 2233 Battery (1 to 4 required)
8163-B Resistance Thermometer

8071-B TYPE G-3 MUELLER BRIDGE



FOR PRECISE, CONVENIENT RESISTANCE-THERMOMETER MEASUREMENTS FROM 0 TO 422.1111 OHMS IN STEPS OF 10 MICROHMS

Constant-temperature chamber with separate thermostatic control unit for critical resistors

Commutator for four-lead resistance thermometer

Milliammeter indicates current in thermometer

Mercury switches provided for higher-resistance decades and commutator

L&N report of calibration supplied with bridge

The Type G-3 Mueller Bridge is a high-precision, high-accuracy, d-c resistance-thermometer bridge for use with either standard or special three- or four-lead resistance thermometers. The bridge resolution of 10 microhms is generally equivalent to 100 microdegrees C. When functioning as a temperature bridge, the initial measurement of R_0 prior to measuring R_t substantially eliminates the residual bridge error. It is this characteristic which makes the bridge resolution meaningful in making high precision temperature measurements.

Two sets of ratio arms permit maximum bridge sensitivity when using either high-value or low-value resistance thermometers. High-stability resistors are enclosed in a thermostatically-controlled constant-temperature chamber with a separate thermostatic control unit. Mercury switches are provided for higher-resistance decades and commutator. An L&N Report of Calibration is furnished with each G-3 Bridge.

SPECIFICATIONS

RANGE—0 to 422.1111 ohms in steps of 0.00001 ohm.

RATIO ARMS—Double set of ratio arms provided; one set of 500 ohms each, one set of 3000 ohms each. A single-turn potentiometer, at apex of each set of ratio resistors, adjusts the ratio arms accurately for unity ratio.

RHEOSTAT ARM—Four Waidner-Wolff (series-parallel) decades of 10 x (0.00001) ohm, 10 x (0.0001) ohm, 10 x (0.001) ohm and 10 x (0.01) ohm. Two decades at the end of the ratio arms of 10 x (0.1) ohm and 10 x (1) ohm. A 10 x (10) ohm decade and a three-position 100 ohms-per-step switch.

LIMITS OF ERROR*—±0.001% or ±20 microhms whichever is larger, using L&N Report of Calibration.

CONSTANT-TEMPERATURE CHAMBER—Insulated chamber with thermostatically controlled heater maintains critical bridge resistors at constant temperature of about 35 C to a stability of ±0.01 C.

GALVANOMETER DAMPING CIRCUIT—Circuit provided with adjustable resistors for either series or parallel galvanometer damping.

MILLIAMMETER—Milliammeter with ranges of 0-2.5 and 0-10 mA indicates thermometer current.

REPORT OF CALIBRATION—L&N Report of Calibration provides initial calibration data. Subsequent calibrations performed by the user, in accordance with directions supplied with the instrument, are checked with an 8070-B Calibrating Resistor.

CASE—Metal, gray enamel; 25″ (l) x 13½″ (w) x 10½″ (d); weight approx. 46 lb.

THERMOSTATIC CONTROL UNIT—(Applicable to Type G-4, G-3 and G-2 Mueller Bridges) Separate unit, supplied with bridge, includes: (1) transistorized heater-control circuit; (2) transformer for galvanometer lamp; (3) on-off indicating lights; (4) terminals for a 6-volt battery; and (5) three cords with plugs for connections to 120-volt, 60-hertz supply, lamp in the 2100 Lamp-and-Scale Device, and heater and mercury thermo-regulator in the bridge. Connections for an external 6-volt storage battery are included as a standby feature; if line power supply is lost, battery provides continuous power for heater in the thermally insulated block. The unit is mounted in a metal case, 8-11/16″ x 5-15/16″ x 6⅛″, and is rated at 20 watts on 120 volts, 60 hertz; weight approx. 7¼ lb.

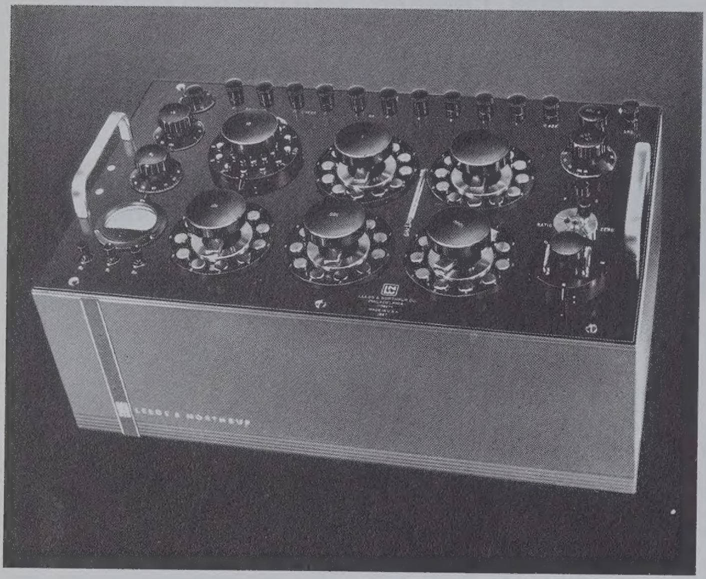
PRICE—$7500.00 (includes Report of Calibration).

**When measuring absolute resistance.*

RECOMMENDED ACCESSORIES

9834 Null Detector, or
2285-b Galvanometer and 2100 Reading Device
Std 2233 Battery (1 to 4 required)
8163-B Resistance Thermometer

8069-B TYPE G-2 MUELLER BRIDGE



FOR PRECISE, CONVENIENT
RESISTANCE-THERMOMETER
MEASUREMENTS FROM
0 TO 111.111 OHMS IN STEPS
OF 100 MICROHMS

Constant-temperature chamber with separate thermostatic control unit for critical resistors

Commutator for four-lead resistance thermometers

L&N report of calibration supplied with bridge

Milliammeter indicates current in thermometer

Mercury switches provided for higher-resistance decades and commutator

The Type G-2 Mueller bridge is invaluable in the research laboratory where measurements must be made at extremely high accuracy, such as the calibration of thermometers, the measurement of boiling and freezing points, etc. The bridge resolution of 100 microhms is generally equivalent to 1 millidegree C. When functioning as a temperature bridge, the initial measurement of R_0 prior to measuring R_t substantially eliminates the residual bridge error. It is this characteristic which makes the bridge resolution meaningful in making high precision temperature measurements.

The bridge features specially-constructed measuring resistors, the enclosing of critical resistors in a thermostatically-controlled constant-temperature chamber to provide accuracy independent of ambient temperature variations, a separate thermostatic control unit, a built-in mercury-contact commutator to permit measurement of four-lead resistance thermometers and mercury switches for higher-resistance decades. An L&N Report of Calibration is furnished with each 8069-B Bridge.

SPECIFICATIONS

RANGE—0 to 111.111 ohms in steps of 0.0001 ohm.

MEASURING ARM—Consists of three shunted decades to give resistance steps of 0.0001, 0.001 and 0.01 ohm, two decades at ends of the ratio arms of 0.1 and 1-ohm steps, and a mercury-cup dial decade of 10-ohm steps.

CONSTANT-TEMPERATURE CHAMBER — Chamber with thermostatically-controlled heater holds measuring resistors constant within ±0.01 C at about 35 C.

COMMUTATOR—Mercury-cup commutator incorporated in top plate adapts instrument for measurements with four-lead resistance thermometers.

RATIO ARMS—1,000 ohms each. Adjustable to equality.

RATIO & ZERO PLUGS—To facilitate adjusting ratio and obtaining zero reading. Located on top plate.

GALVANOMETER DAMPING—An adjustable resistor can be connected, by means of a switch, either in series or in parallel with a galvanometer.

BRIDGE-CURRENT REGULATOR—Three pushbuttons select different bridge currents. Two are adjustable.

MILLIAMMETER—Range 0 to 5 mA. Indicates current in the resistance thermometer.

LIMIT OF ERROR*— ±0.001% or 50 microhms, whichever is larger, using Report of Calibration corrections.

REPORT OF CALIBRATION—L&N Report of Calibration provides initial calibration data. Subsequent calibrations performed by the user, in accordance with directions supplied with the instrument, are simply checked with an 8070-B Calibrating Resistor.

CASE—Metal, gray enamel finish; 9¼" x 21¼" (l) x 13" (w); 10" (d with cover); weight approx. 40 lbs.

THERMOSTATIC CONTROL UNIT—Separate unit, supplied with bridge. For description, see Type G-3 Mueller Bridge.

PRICE—$4500.00. (includes Report of Calibration).

**When measuring absolute resistance.*

RECOMMENDED ACCESSORIES

9834 Null Detector, or
2284-d Galvanometer, and
2100 Reading Device
Std 2233 Battery (1-5 cells required)
8070-B Calibrating Resistor (10.01 ohms)
8160 Platinum Resistance Thermometer, or
8163 Platinum Resistance Thermometer, or
8164 Platinum Resistance Thermometer

8067 TYPE G-1 MUELLER BRIDGE

FOR RESISTANCE-THERMOMETER MEASUREMENTS FROM 0 TO 81.111 OHMS IN STEPS OF 100 MICROHMS

Designed for measurements with three-terminal thermometers

Commutator for four-terminal resistance thermometers available

Report of calibration available

Where the accuracy of the Type G-2 Mueller Bridge is not required, the Type G-1 may be used for precision temperature measurements by the electrical resistance-thermometer method. The principal difference between the two models is the omission from the G-1 of the constant-temperature chamber, its heater and the thermostatic control unit. The bridge resolution of 100 microhms is generally equivalent to 1 millidegree C. When functioning as a temperature bridge, the initial measurement of R_0 prior to measuring R_t substantially eliminates the residual bridge error. It is this characteristic which makes the bridge resolution meaningful in making high precision temperature measurements. Measuring resistors are mounted on standard switch assemblies and are subject to slight changes in resistance with ambient temperature. A commutator for adapting the bridge for measurements with four-terminal potential type resistance thermometers is available for use with the G-1. An L&N Report of Calibration is available as an extra-cost option.

SPECIFICATIONS

RANGE—0 to 81.111 ohms, in steps of 0.0001 ohm.

MEASURING ARM—Consists of three shunted decades to give steps of 0.0001, 0.001, and 0.01 ohm, two decades at the ends of the ratio arms of 0.1 and 1-ohm steps, and binding posts on the end of the measuring arm by means of which 0, 10, 20, 25, 25.5, 30, 40, 50, 60 or 70 ohms may be inserted.

RATIO ARMS—500 ohms each. Adjustable to equality.

LIMITS OF ERROR—±0.0002 ohm up to one ohm, ±0.02% from one ohm to 81.111 ohms.

REPORT OF CALIBRATION—An L&N Report of Calibration provides initial calibration data. Subsequent calibrations performed by the user, in accordance with directions supplied with the instrument, are simply checked with an 8070-B Calibrating Resistor.

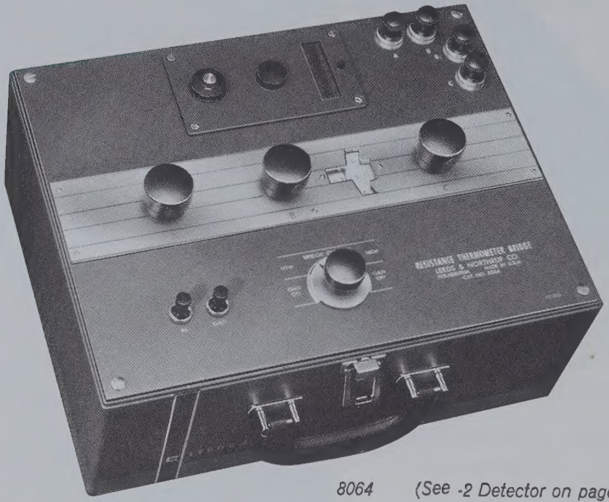
CASE—Metal, gray enamel finish, with cover; 11¼″ (w) x 14¾″ (l) x 5¼″ (d), 6⅛″ (d with cover); weight about 25 lb.

PRICE—$1450.00; Report of Calibration (suffix "-B"), add $400.00.

RECOMMENDED ACCESSORIES

2285-b Galvanometer
2100 Reading Device
Std 2233 Battery (1-4 cells required)
8070-B Calibrating Resistor (10.01 ohms)
8068 Commutator for four-terminal resistance thermometers, Price $290.00.
8160 Platinum Resistance Thermometer, or
8163 Platinum Resistance Thermometer, or
8164 Platinum Resistance Thermometer

8064 and 8064-2 PRECISION D-C RESISTANCE THERMOMETER BRIDGE



8064 (See -2 Detector on page D-14)

FOR PRECISE RESISTANCE-THERMOMETER MEASUREMENTS FROM 0 TO 160.1 (OR 1060.1) OHMS READABLE TO 0.001 OHM

Direct-reading—single row of digits plus scale reading

May be used with either three- or four-lead resistance thermometers

Self-contained with light-beam galvanometer or null detector

These modified Wheatstone bridges are ideal for precise measurements of temperature and temperature difference by the resistance - thermometer (Thermohm) method. They are available in a selection of two ranges (see specifications), and are completely self-contained with internal galvanometer or null detector and batteries. Bridges have a dual slidewire for ratio compensation, four binding posts for connecting either three- or four-lead resistance thermometers, and a function switch to select bridge current (four-position for low range; eleven-position for high range). An L&N Report of Calibration is available (add suffix "-B").

SPECIFICATIONS

LIST NUMBERS—8064 (Low range, galvanometer); 8064-A (High range, galvanometer); 8064-2 (Low range, null detector): 8064-A2 (High range, null detector).

RANGE—8064: 0 to 160.1 ohms; 8064-A: 0 to 1060.1 ohms.

RATIO ARMS—Fixed at approximately 130 ohms, unity ratio circuit.

RHEOSTAT ARM—Two switches, one of 15 steps of 10 ohms per step, the other of 10 steps of 1 ohm per step—plus a slidewire shunted to 1.10 ohms.

LIMITS OF ERROR—±0.05% of reading or ±0.005 ohms, whichever is larger.

With L&N Report of Calibration: ±0.03% or ±0.003 ohm, whichever is larger.

GALVANOMETER (8064)—Built-in, light-beam; sensitivity sufficient to detect better than 0.005-ohm change when measuring 160 ohms with 5 mA flowing through the resistance thermometer.

NULL DETECTOR (8064-2)—Built-in, electronic; sensitivity 0.001 ohm at 160 ohms with 5mA flowing through the resistance thermometer decreasing to 0.01 ohm at 1060 ohms with 0.5mA.

BINDING POSTS—Four, for connecting either 3- or 4-lead resistance thermometer to bridge.

KEYS—One detector, one battery.

BATTERIES—Three; one 1½-volt for measuring circuit. Two 1½-volt for galvanometer lamp (8064); Two 6-volt for detector (8064-2).

CASE—Gray metal case with handle and slip-hinged removable lid; 14¼" x 11½" x 7½"; weight approx. 20½ lb.

PRICE—8064: $595.00; 8064-2: $700.00; "-B" add $175.00; 8064-A: $615.00; 8064-A2: $690.00; "-B" add $200.00.

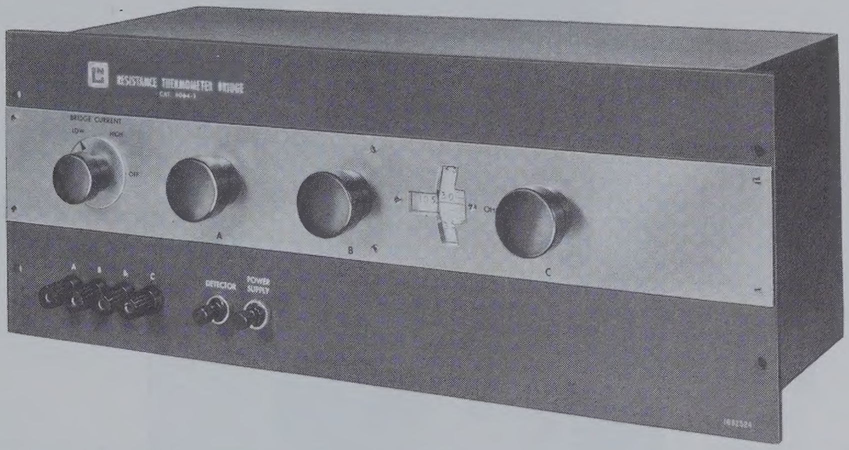
OPTIONAL ACCESSORIES

099007 Line - operated Lamp Power Supply for galvanometer, Price $30.00.

099055 Line-operated Power Supply (8064-2), Price $38.00.

124403 Kit to convert 8064 to 8064-A, Price $125.00.

8064-1 and 8064-A1 PANEL-MOUNTED PRECISION D-C RESISTANCE THERMOMETER BRIDGE



FOR PRECISE RESISTANCE-THERMOMETER MEASUREMENTS FROM 0 TO 160.1 (OR 1060.1) OHMS READABLE TO 0.001 OHM

Direct-reading—single row of digits plus scale reading

May be used with either three- or four-lead resistance thermometers

Designed for mounting in standard 19″ panel

For precise measurement of temperature, the 8064-1 three-dial d-c Wheatstone bridge features panel-mounting design to provide unusual flexibility in application. This versatile temperature bridge is a precision measuring tool of many diverse applications. With an appropriate detector, the 8064-1 or 8064-A1 bridge will monitor variations in temperature such as cooling rates, temperature coefficients, etc. On the production line it can be mounted on a mobile rack, used with a recorder or null detector and used as a precise reference for repetitive checking of numerous products and components. A precision measurement module, the 8064-1 or 8064-A1 can be combined with auxiliary equipment to provide a measurement facility with virtually unlimited applications. Bridges have a dual slidewire for ratio compensation, four binding posts for connecting either three- or four-lead resistance thermometers, and a function switch to select bridge current (four-position for low range; eleven-position for high range). An L&N Report of Calibration is available (add suffix "-B").

SPECIFICATIONS

LIST NUMBERS—8064-1 (Low range); 8064-1A (High range).

RANGE—8064-1: 0 to 160.1 ohms; 8064-A1: 0 to 1060.1 ohms.

RATIO ARMS—Fixed at approximately 130 ohms, unity ratio circuit.

RHEOSTAT ARM—Two switches, one of 15 steps of 10 ohms per step, the other of 10 steps of 1 ohm per step—plus a slidewire shunted to 1.10 ohms.

LIMITS OF ERROR—±0.05% of reading or ±0.005 ohms, whichever is larger.
With L&N Report of Calibration: ±0.03% or ±0.003 ohm, whichever is larger.

POWER SUPPLY—One 1½-volt battery with maximum current drain of 23 mA.

KEYS—One lock-down detector key; one lock-down battery key.

INPUT—Front-mounted 5-way terminal posts and rear terminals for three or four-lead resistance thermometers.

DETECTOR—Not supplied; rear detector terminals for external null detector.

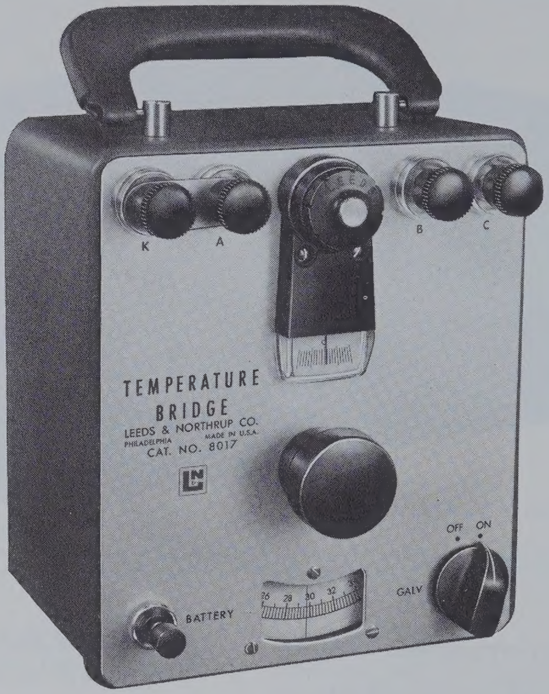
CASE—Gray metal, full panel width; 19″ (w) x 6-31/32″ (h) x 7″ (d); weight approx. 15 lb.

PRICE — 8064-1: $520.00; "-B" add $175.00; 8064-A1: $595.00; "-B" add $200.00.

RECOMMENDED ACCESSORIES

9834-1 Null Detector, or
2437-1-☐☐ Null Detector.

8017 COMPACT D-C TEMPERATURE BRIDGE



FOR ROUTINE TEMPERATURE MEASUREMENTS OF ANY SPAN OF 20 F OR MORE (−180 F TO −160 F, 0 TO 10 C, 1800 TO 1820 F, ETC.—SPECIFY DESIRED RANGE)

Slidewire calibrated directly in temperature

Pointer-type galvanometer

May be used with either three- or four-lead resistance thermometers

Completely portable with sturdy, lightweight metal case

This portable, compact, direct-reading bridge measures temperature with resistance thermometer detectors in heating, ventilating and air-conditioning applications. It provides higher accuracy than thermocouples at a cost comparable to lower-grade bulb or thermocouple instruments. The 8017 is a battery-powered d-c Wheatstone bridge designed for simplest operation and direct readout in degrees F or C. Binding posts are provided for connecting three- or four-lead Thermohm® (resistance thermometer) elements as well as an auxiliary multipoint Thermohm selector switch.

SPECIFICATIONS

RANGE—Any direct-reading span of 20 F (10 C) or more for any standard Thermohm detector.

RATIO ARMS—Fixed at approximately 300 ohms.

RHEOSTAT ARM—Single slidewire calibrated directly in temperature range using specified Thermohm detector.

LIMITS OF ERROR—±0.3% of span.

GALVANOMETER—Built-in, pointer type; sensitivity sufficient to detect at least ±0.3% of range for any range with a temperature calibration of 20 F or more.

KEYS—One battery key.

BINDING POSTS—Three for 3- or 4-lead Thermohm, and one for multiple Thermohm detectors used with an external switch.

BATTERIES—Two 1½-V batteries connected in parallel.

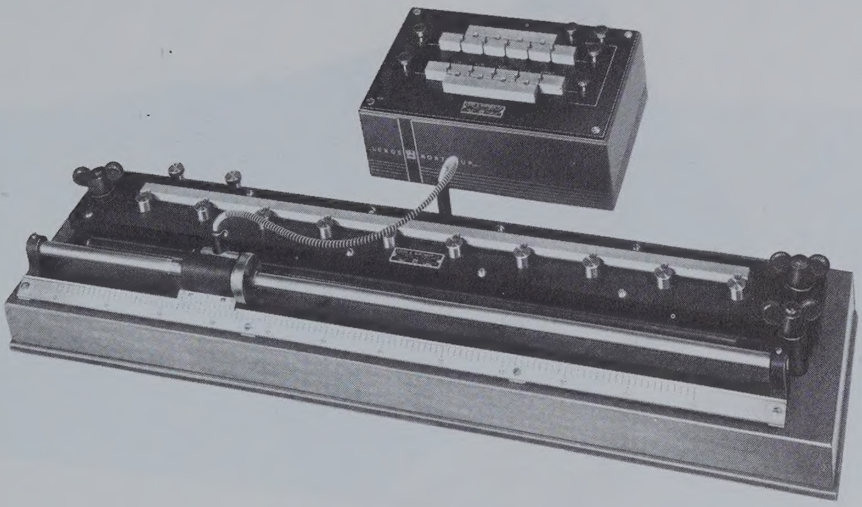
CASE—Gray metal case with carrying handle; 7¾″ x 6⅛″ x 5⅞″; weight approx. 4½ lb.

PRICE—$250.00.

OPTIONAL ACCESSORIES

039733 Leather Carrying Case, Price $37.25.
R-506-N-1 Check Coil, Price $19.00.

4300/4320 PRECISION KELVIN BRIDGE



FOR PRECISE MEASUREMENTS
OF LOW RESISTANCES
UP TO 1 OHM, READABLE
TO 0.01 MICROHM
ON LOWEST RANGE

Ratio box—double set of ratio resistors (plug-and-block selected); binding posts provided for detector, adjustable standard and resistance under test

Adjustable standard—large diameter calibrated bar and nine fixed resistors; current terminals provided for connections to external battery

Comprising the 4300 Adjustable Low-Resistance Standard and the 4320 Kelvin-Bridge Ratio Box, this high-precision bridge has selectable fixed ratios and a continuously adjustable standard. The bridge is used only for measurements of low resistance components such as wires, rods, switches, coils, windings, and meter shunts. The 4300 Adjustable Standard consists of a large-diameter calibrated bar and nine fixed resistors mounted on a mahogany base. The resistors utilize plug-and-block connections, for very reproducible low-value contact resistance. Fine adjustment is made by moving an adjustable knife-edge contact along the bar, providing excellent resolution. The 4320 Ratio Box contains the bridge ratio arms consisting of a double set of resistors, which are plug-and-block selected. Overall range is 0.01 microhm to 1 ohm. L&N Reports of Calibration are available (add suffix "-B").

SPECIFICATIONS

4300 ADJUSTABLE STANDARD

RANGE OF 4300/4320—Extremes of ratio available: 100:10,000—1.01 ohms maximum, each vernier division 100 microhms. 10,000:100 — 0.000101 ohm maximum, each vernier division 0.01 microhm.

TOTAL RESISTANCE—Consists of 9 fixed steps of 0.001 ohm, plus a continuously adjustable bar of 0.001 ohm, read from scale with 110 divisions having vernier providing readability of 1 microhm.

LIMITS OF ERROR—Of fixed steps: up to 0.005 ohm, ±2 microhms; above 0.005 ohm, ±0.04%. Of adjustable bar: ±2 microhms.

CURRENT RATING—For 10-minute period: 50 A in entire standard, 150 A in bar alone. For continuous duty: 30 A in entire standard, 90 A in bar alone.

BASE—Polished mahogany; 30⅞" x 8⅞" x 6⅞"; weight approx. 21½ lb.

PRICE—$1250.00, "-B" add $275.00.

4320 KELVIN BRIDGE RATIO BOX

RATIO ARMS—Double set of ratio resistors: 100, 300, 400, 1000, 10,000 ohms respectively, plug-and-block selected.

LIMITS OF ERROR—Of ratios: ±0.015%; of ratio resistors: ±0.05% of nominal value.

CASE—Metal, with gray enamel finish; 11⅜" x 7⅜" x 6⅛"; weight approx. 10 lb.

PRICE—$550.00, "-B" add $120.00.

RECOMMENDED ACCESSORIES

2430-c Galvanometer
3294 Battery Key
4308 Current and Potential Clamps for heavy rod or cable, Price $355.00.
Std 2233 Battery
4885 Yard Arm Scales for wire samples, Price $225.00.

4287 and 4287-2 PRECISION D-C KELVIN BRIDGE

4287
(See -2 Detector on page D-14)

FOR ROUTINE LOW-RESISTANCE MEASUREMENTS FROM 0.0001 TO 110.1000 OHMS READABLE TO 0.01 MICROHM ON LOWEST RANGE.

Direct-reading—single row of digits plus scale reading

Self-contained with light-beam galvanometer or null detector

Terminals provided for external detector, unknown, external standard and external battery

Improved accuracy and sensitivity, wider range, increased reading ability and a direct-reading arrangement make these precision bridges especially useful for routine low resistance measurements in laboratories and for manufacturers of motors, electronic components, etc. The portable bridges are completely self-contained with a high-sensitivity light-beam galvanometer or null detector and provision for substituting external standard, null detector, and power supply for the internal components provided. The use of an external standard provides for range extension in either direction. An L&N Report of Calibration is available (add suffix "-B").

SPECIFICATIONS

LIST NUMBERS—4287 (Galvanometer); 4287-2 (Null detector).

RANGE—0.0001 to 110.100 ohms in six ranges. (Can be extended down to 1 microhm with auxiliary standards).

RATIO ARMS—One arm fixed at 10,000 ohms; other consists of two decades, 100 to 1000 ohms and 0 to 90 ohms—plus slidewire adjustable from 0 to 11 ohms.

STANDARD ARM—Six standard resistors of 0.01, 0.1, 1, 10, 100, and 1000 ohms; switched as four-terminal elements.

LIMITS OF ERROR—±0.05% of reading. Improves to ±0.03% as "A" dial is switched from the 1 to the 10 position. With L&N Report of Calibration: ±0.02%.

GALVANOMETER (4287)—Built-in, light-beam; sensitivity sufficient to detect ±0.1% change when measuring 0.0001 ohms, ±0.02% when measuring 0.001 ohms, ±0.01% or better when measuring 0.01 ohms or more.

NULL DETECTOR (4287-2)—Sensitivity better than 0.02% change when measuring 0.0001 ohm, better than 0.005% when measuring 0.001 ohm, better then 0.001% when measuring 0.01 ohm or more.

KEYS—Two for low and high detector-sensitivity selection and one for battery.

BINDING POSTS—Eight; four for unknown resistance, four for substitution of external standard for internal ones.

BATTERIES—Three; one 1½-volt for measuring circuit. Two 1½-volt for galvanometer lamp (4287); two 6-volt for detector (4287-2).

CASE—Metal case with handle and slip-hinged removable lid; 14¼" x 11½" x 7½"; weight approx. 23½ lb.

PRICE—4287: $675.00; 4287-2: $750.00; "-B" add $250.00.

OPTIONAL ACCESSORIES

037768 Cable for external null detector, Price $21.00.

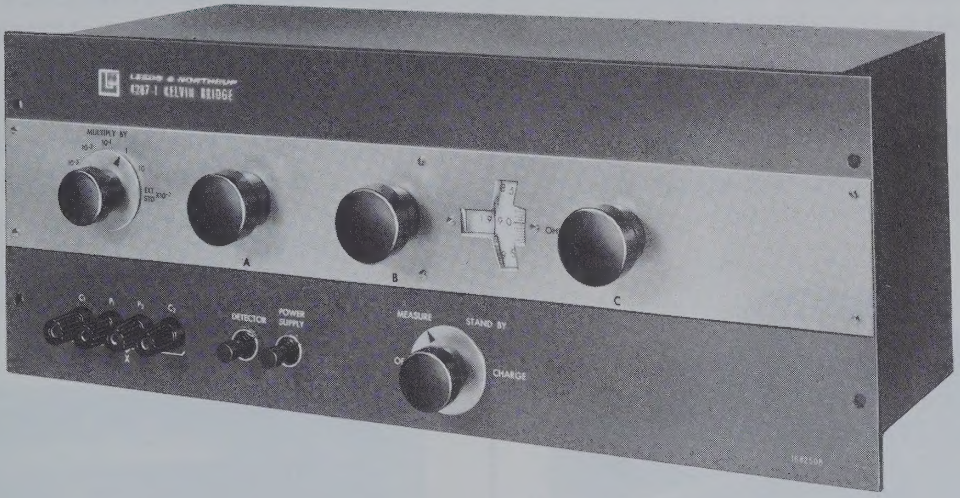
099007 Line-operated Lamp Power Supply (4287), Price $30.00.

099055 Line-operated Power Supply (4287-2), Price $38.00.

124297 Kit for four terminal measurements, Price $21.75.

4333 (0.001-ohm) and 4334 (0.0001-ohm) External Standard Resistors

4287-1 PANEL-MOUNTED PRECISION D-C KELVIN BRIDGE



FOR ROUTINE LOW-RESISTANCE MEASUREMENTS FROM 0.0001 TO 110.1000 OHMS READABLE TO 0.01 MICROHM ON LOWEST RANGE

Direct-reading—single row of digits plus scale reading

Designed for mounting in standard 19″ panel

For precise measurement of resistance, these d-c bridges feature panel-mounted design to provide convenience and flexibility in application. These precision bridges are ideal for many diverse resistance measurements in the laboratory or factory. With a suitable detector they can be used to monitor changes and variations in resistance; with a recorder and a deviation amplifier they can provide precision control of numerous functions; on the production line they can provide a reference for repetitive checking of resistive elements such as heater windings. The use of an external standard provides for range extension in either direction. An L&N Report of Calibration is available (add suffix "-B").

SPECIFICATIONS

RANGE—0.0001 to 110.100 ohms in six ranges. (Can be extended down to 1 microhm with auxiliary standards).

RATIO ARMS—One arm fixed at 10,000 ohms; other consists of two decades, 100 to 1000 ohms and 0 to 90 ohms—plus slidewire adjustable from 0 to 11 ohms.

STANDARD ARM—Six standard resistors of 0.01, 0.1, 1, 10, 100, and 1000 ohms; switched as four-terminal elements.

LIMITS OF ERROR—±0.05% of reading. Improves to ±0.03% as "A" dial is switched from the 1 to the 10 position. With L&N Report of Calibration: ±0.02%.

DETECTOR—Not supplied; rear terminals for external null detector.

KEYS—One lock-down detector key; one lock-down, high current battery key.

INPUT—Front-mounted 5-way posts for "unknown"; rear terminals for "unknown" and external standard.

POWER SUPPLY—Rechargeable battery, 7 amp-hour rating; Line-operated recharging circuit has "trickle" charge and 14 hour, "fast" charge features.

CASE—Metal cover, gray baked enamel finish; 19″ panel width x 6-31/32″ (h) x 7″ (d); weight approx. 15 lb.

PRICE—$570.00, "-B" add $250.00.

RECOMMENDED ACCESSORIES

9834-1 Null Detector, or
2437-1-☐☐ Null Detector

OPTIONAL ACCESSORIES

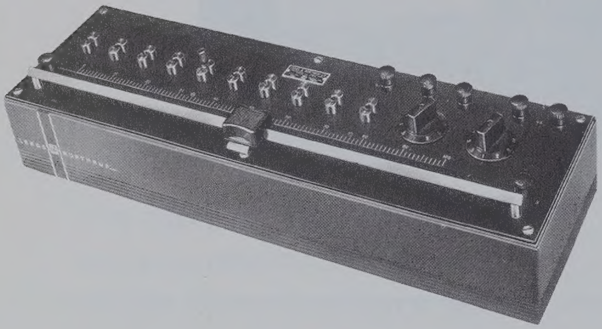
124297 Kit for four terminal measurements, Price $23.75.
4333 (0.001-ohm) and 4334 (0.0001-ohm) External Standard Resistors

4306 GENERAL-PURPOSE KELVIN BRIDGE

FOR MEASUREMENTS UP TO 1 OHM
READABLE TO 1 MICROHM ON
LOWEST RANGE

Dial-selected ratios—seven values

Adjustable standard consists of adjustable bar and nine fixed resistors



This general-purpose bridge was designed especially for low-resistance measurements where the accuracy of the Precision Kelvin Bridge is not required. It consists of clearly marked dials for selecting the desired ratios, and a resistance standard comprising a continuously adjustable graduated bar and nine fixed resistors operated by means of a plug-and-block. An L&N Report of Calibration is available (add suffix "-B").

SPECIFICATIONS

RANGE—0.000 01 to 1 ohm.

RATIO ARMS—Seven ratio values: 0.1, 0.2, 0.5, 1, 2, 5, 10.

STANDARDS—Fixed: 9 x 0.01 ohm; plug-and-block selected. Adjustable: 0.01 ohm, continuously adjustable.

LIMITS OF ERROR—Of ratio: ±0.05%; of fixed standards: ±0.05%; of adjustable standard: ±0.2 scale division. With L&N Report of Calibration: of ratio factors: ±0.02%; of resistance standards: ±0.03% or ±0.000 01 ohm, whichever is larger.

CURRENT RATING—For continuous duty: 8 A in entire standard, 18 A in bar alone.

CASE—Metal, gray enamel finish with protective cover; 23½" x 7" x 5⅝"; weight approx. 14 lb.

PRICE—$850.00; "-B" add $300.00.

RECOMMENDED ACCESSORIES

2435-b Galvanometer
10609 Transformer for galvanometer lamp
3702 Galvanometer Key
Std 2233 Battery
4308 Current and Potential Clamps, Price $355.00.

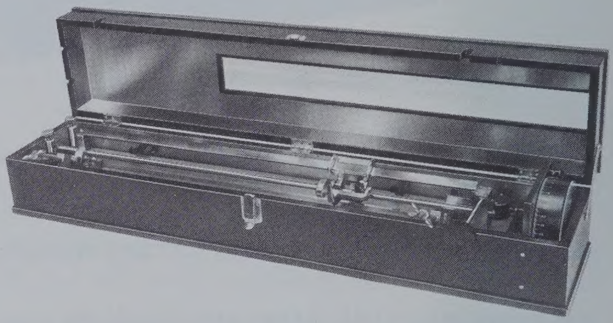
4870 HOOPES CONDUCTIVITY BRIDGE

FOR RAPID, ROUTINE COMPARISON
OF WIRE AND ROD SAMPLES USING
COPPER CONDUCTIVITY STANDARDS

Scale calibrated to read percent conductivity of sample

Copper-lined compartment may be oil-filled for faster temperature equalization

Calibrated slidewire to compensate for error in weight



The 4870 Hoopes Conductivity Bridge is a special type of Kelvin bridge useful for the rapid, routine comparison of resistivity of copper or aluminum wire rods. Interchangeable standards adapt the bridge for testing wires throughout an extended range of sizes. The scale is calibrated to read directly in percent conductivity, eliminating the need for calculations. The sample and standard are enclosed in the same copper-lined compartment to assure temperature uniformity. This compartment may be oil-filled for faster temperature equalization, and will accommodate several samples for temperature uniforming. A glass window in the lid permits reading the scale with the cover closed.

SPECIFICATIONS

CONDUCTIVITY RANGE—0 to 105% of standard.

LIMIT OF ERROR—±0.2% conductivity when used with 4872 Copper Standards.

WEIGHT COMPENSATOR — Adjustable slidewire, range ±15%.

CASE—Oak, 48" x 10" x 9"; weight approx. 70 lb.

PRICE—$3980.00.

RECOMMENDED ACCESSORIES

4871 Balance, P. O. R.
4872 Copper Standards, P. O. R.
4890 Rheostat Switch, Price $400.00.
4895 Storage Battery, Price $39.70.
2430-c Galvanometer

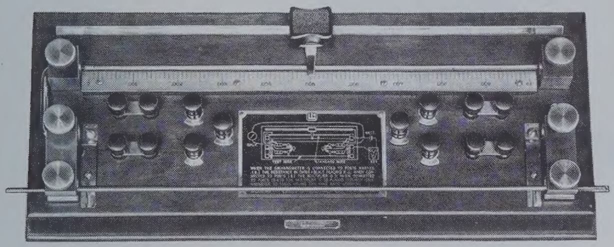
4340 STUDENTS' KELVIN BRIDGE

FOR INSTRUCTION AND EXPERIMENTATION IN THE KELVIN-BRIDGE METHOD

Three ratio values

Copper wire with statement of resistance value supplied for checking

Binding posts provided for connecting external galvanometer and battery



Designed especially for instruction in the Kelvin-bridge method and for student experimentation, this is a simplified model of the General-Purpose Kelvin Bridge. Reduced to essentials, all components—calibrated standard, ratio arms, sample holder, yoke and binding posts—are mounted on a mahogany base. A metal plate which shows the Kelvin-bridge circuit diagram is also mounted on this base. A sample of heavy copper wire, with a statement of its resistance between two points at a specified temperature, is supplied with the bridge.

SPECIFICATIONS

RANGE—0.00001 ohm to 0.1 ohm.

RATIO ARMS—Three ratio values: 0.1, 1 and 10.

STANDARD—Bar, total resistance, 0.01 ohm. Attached scale has 100 divisions.

LIMITS OF ERROR—Of ratio: ±0.2%. Of standard: ±1 scale division.

CURRENT RATING—For continuous duty, 15 A.

BASE—Polished mahogany: 19⅝" x 8¼" x 4¼"; weight approx. 9 lb.

PRICE—$475.00.

RECOMMENDED ACCESSORIES

2340-c Galvanometer, or
2340-b Galvanometer, or
2239-a Galvanometer
3702 Galvanometer Key
Std 2233 Battery

4288 COMPACT D-C KELVIN BRIDGE

FOR ROUTINE MEASUREMENTS FROM 0.0001 TO 11.00 OHMS READABLE TO 10 MICROHMS ON LOWEST RANGE

Direct-reading slidewire scale

Batteries included with provision for external batteries

GALV
KELVIN BRIDGE
CAT. NO. 4288
BATTERY

Designed for rapid testing of low resistances, this rugged bridge is especially applicable for the routine measurement of low-resistance wires, rods, brushes, windings, contacts and other electrical conductors. Although the bridge is completely self-contained and includes internal batteries, provision is made for the use of an external power supply.

SPECIFICATIONS

RANGE—0.0001 to 11.00 ohms in five ranges.

RATIO ARMS—Adjustable slidewires calibrated 0.010 to 0.110 ohm.

STANDARD ARM—Internal resistance standards provide multipliers of 0.01, 0.1, 1, 10, and 100. Switched as four-terminal elements.

LIMIT OF ERROR—±1% of reading.

GALVANOMETER—Built-in, pointer type; sensitivity to detect a change of 1% or less throughout range.

KEYS—One galvanometer, one battery.

BATTERIES—Four 1½-V high-energy "D" batteries connected in parallel.

CASE—Metal case with carrying handle; 7¾" x 6⅛" x 5⅞"; weight approx. 5½ lb.

PRICE—$270.00.

OPTIONAL ACCESSORIES

039733 Leather Carrying Case, Price, $37.25.
124297 Kit of leads for remote four-terminal measurements, Price $23.75.

1511 MODIFIED SCHERING BRIDGE

Complete 1511-S Assembly

PRECISION MEASUREMENTS OF CAPACITANCE AND DIELECTRIC LOSS AT HIGH WORKING VOLTAGES OF 1 TO 25 KV

Provision for balancing-out stray capacitances and bringing all shielding to ground potential

Safety gaps in bridge to prevent high voltage on control panel if test sample breaks down

Direct reading in dissipation factor

The Modified Schering Bridge permits high-voltage measurements at commercial power frequencies to determine the power factor and other dielectric characteristics of power cables, insulating oils, insulating materials for high-voltage cables, etc. This instrument consists of the low-voltage bridge arms with auxiliary adjustment for potential of "D" point, and includes a ratio checking unit and transformer for preliminary shield-bridge balance. Provision is made for balancing-out stray capacitances and bringing all shielding to ground potential. Safety gaps in the bridge prevent high voltage on the control panel in case of breakdown of the test sample. The bridge is direct-reading in dissipation.

SPECIFICATIONS

RANGE—Capacitance, 40 pF to 0.02 μF using 100 pF standard air capacitor. Dissipation factor, 0.0001 to 1.0 corresponding to 0.0001 to 0.7 power factor.

RATIO ARMS—(Not included in price) Fixed-standard 100 pF high-voltage air capacitor for one, test specimen for the other.

COMPARISON STANDARD—Adjustable capacitors range, 10 (0.1 + 0.01 + 0.001 + 0.0001 μF) + 110 pF for dissipation factor readings; and adjustable decade resistors range, 10(0.1 + 1 + 10 + 100 + 1000 ohms) + (0 to 0.105) ohm for capacitance readings.

LIMITS OF ERROR—Of capacitance ±0.25% exclusive of the error of the standard capacitor. Of dissipation factor ±(1% + 0.000 005). Of power factor, same as for dissipation factor for scale readings to 0.1, and for values above 0.1 using conversion of natural tan to sine.

CASE—Shielded for vertical mounting; 29″ x 22¼″ x 7¼″.

PRICE—On request.

RECOMMENDED ACCESSORIES

1160 Cylindrical Type Air Capacitor, 10 kV, or
1161 Cylindrical Type Air Capacitor, 25 kV
High-Voltage Step-up Transformer
9844-60 A-C Electronic Null Detector

SCHERING-BRIDGE ASSEMBLIES

1513

1511-S CONSOLE-MOUNTED MODIFIED SCHERING BRIDGE

The 1511-S Assembly consists of a 1511 Modified Schering Bridge, an electronic a-c null detector, a primary voltage control for the testing transformer, and safety devices, all console-mounted in a compact assembly within a grounded shield.

CONSOLE—Gray baked-enamel finish; ball-type casters with brakes on front casters; 55″ (l) x 30″ (w) x 52¾″ (h); weight approx. 300 lb.

PRICE—On request.

1513 HIGH-CURRENT 60-HERTZ SCHERING BRIDGE, CONSOLE-MOUNTED

The 1513 Assembly consists of a high-current Schering Bridge and an electronic a-c null detector, console-mounted, for measuring the power factor and capacitance of cables.

SPECIFICATIONS

POWER FACTOR RANGE—0.001% to 20%. Range actually measures dissipation factor, but there is little difference between dissipation factor and "power factor" over this range and the dials are indexed power factor for convenience.

CAPACITANCE RANGE—0.000 076 to 2.0 μF. Direct reading in microfarads when capacitor used as a standard is 100 pF (corrections must be made for standards of other values).

LIMITS OF ERROR—0.001 to 10% power factor: ±1.0% of reading or 0.005% power factor, whichever is greater; 10 to 20% power factor: 1 to 5% of the reading.

TEST VOLTAGES—Limiting factors are the current ratings of shunts internal to the bridge. Test voltages ranging from 13.2 kV to 125 kV may be applied depending on the specimen capacitance. For small-capacitance specimens at low test voltages, measurements of power factor are limited by the sensitivity of the null detector which is approx. 0.1 μV per division.

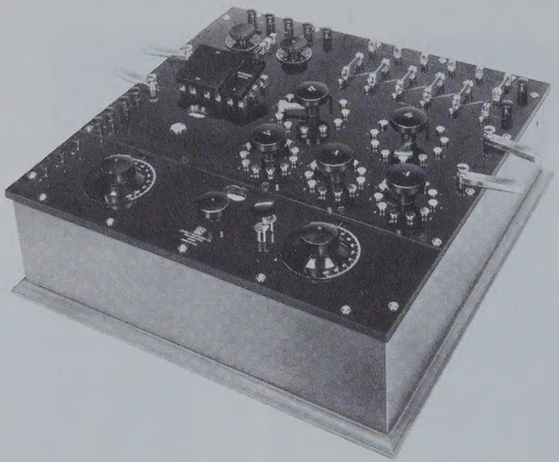
CONSOLE—Bridge mounted on desk top; detector-sensitivity and shield-balance, coarse-voltage controls mounted in desk pedestals; ball-type rollers; 56¼″ (h) x 55″ (l) x 30″ (w); weight approx. 300 lb.

PRICE—On request.

RECOMMENDED ACCESSORIES FOR 1511-S & 1513

1160 Cylindrical Type Air Capacitor, 10 kV, or
1161 Cylindrical Type Air Capacitor, 25 kV
High Voltage Step-up Transformer

4666 JONES BRIDGE



FOR PRECISE ELECTROLYTIC
CONDUCTIVITY MEASUREMENTS
WITH 60,000-OHM RANGE

Modified Wagner ground eliminates capacitance-to-ground errors

Binding posts for external standards for extending range

Grounded metal shield lines front quarter of box

Normally usable to 2000 hertz

Designed for use in making the most precise measurements possible in the field of electrolytic-conductivity research, the Grinnel-Jones Electrolytic-Conductivity Bridge is widely used by scientists to study the nature of solutions and the fundamental nature and constitution of matter. The Jones Bridge also measures the temperature of solutions with a bath resistance thermometer. Construction features include the use of a modified Wagner earthing device to eliminate errors due to capacitance to ground, two adjustable air capacitors to compensate for the conductivity-cell capacitance in making the phase-angle balance of the bridge, and bifilar and woven resistors to minimize variation in effective a-c resistance and d-c value.

SPECIFICATIONS

RANGE—60,000 ohms in steps of 0.1 ohm. Slidewire, between rheostat and "X" arm of bridge, permits adjustment of bridge balance to precision of ±0.001 ohm. Binding posts provided for connecting external resistance to extend range.

RATIO ARMS—Two 1000-ohm resistors adjusted to equality of d-c resistance within ±0.01%. Slidewire between ratio resistors adjusts ratio arms to equality within ±0.0002% and provides a range of ratio from 0.999 to 1.001.

RHEOSTAT—Five decades: 9(1000 + 100) ohms and 10(10 + 1 + 0.1) ohms, plus 5 knife-switch selected steps of 10 K ohms.

LIMITS OF ERROR—At 20 to 30 C and relative humidity not over 70%, ±0.02%: with calibration checks, above 100 ohms, ±0.005% or better attainable. Effective a-c resistance within ±0.001% of d-c at 1000 hertz. These limits of error apply under normal conditions of use for one year after date of shipment.

ADJUSTABLE CAPACITORS—50 to 1000 pF and 10 to 120 pF, connected across rheostat and "X" arm of bridges respectively, compensate for capacitance of conductivity cell and provide phase-angle balance. Additional capacitance may be connected to terminals S_1 and S_2 if necessary.

GROUND CONNECTION—Wagner-type, modified.

TRANSFORMERS—Input and detector transformers, externally mounted.

CASE—Polished mahogany, with cover; 24⅝" x 24⅝" x 9¾"; weight approx. 65 lb.

PRICE—$5000.00.

RECOMMENDED ACCESSORIES

4940 Series Conductivity Cells
To Be Supplied By User:
(1) Tuned Amplifier and Null Detector—General Radio Type 1232A
(2) Audio Frequency Oscillator—Hewlett-Packard Model 201-C

OPTIONAL ACCESSORY

8401 Constant-Temperature Bath

4866 CONDUCTIVITY-RESISTIVITY INDICATOR

FOR CONDUCTIVITY MEASUREMENTS
TO 0.000 000 1 MHO/CM AND
RESISTIVITY MEASUREMENTS
TO 10,000,000 OHMS/CM

Scale multipliers plug-and-block selected

Pointer-type galvanometer

Double-dial compensator

4960 ELECTROLYTIC-RESISTANCE INDICATOR

FOR CONDUCTIVITY MEASUREMENTS
IN TERMS OF RESISTANCE FROM
0.3 to 30,000 OHMS

Scale multipliers plug-and-block selected

Pointer-type galvanometer

Two L&N portable indicators are available to measure electrolytic conductivity of various solutions or to check steam or condensate purity. Both are ideal for control work; where it is impractical to carry samples to the laboratory, they permit making measurements at the process location. Each bridge is reduced to essentials for portability and convenience and is so constructed that maintenance is negligible. These indicators operate on 120 volts, a-c and are protected against ground by an isolating transformer which separates the measuring current from direct connection to the power circuit.

The 4866 Indicator has two scales, calibrated in conductivity and resistivity, and provides two compensators, for cell constant and solution temperature. The 4960 Indicator measures conductivity in terms of resistance, and provides no compensation for temperature of the electrolyte.

SPECIFICATIONS-4866 CONDUCTIVITY-RESISTIVITY INDICATOR

RANGE—Specific conductance: 0.012 to 0.000 000 1 mho per centimeter. Specific resistance: 80 to 10,000,000 ohm-centimeters.

LIMITS OF ERROR—Of conductance scale: 0.3% of its 1 to 12 range; of compensators: 0.002 cell constant and 1 C solution temperature.

STANDARDS—Five: 38, 380, 3800, 38,000 and 380,000 ohms.

COMPENSATORS—Two: one for cell constant between 0.07 and 0.12; one for solution temperature between 5 and 45 C.

POWER SUPPLY—120 volts, 60 hertz (specify 4866-60) or 50 hertz (4866-50).

CASE—Oak, with hinged lid and carrying handle; 13¾" x 9½" x 6½"; weight approx. 17 lb.

PRICE—4866-50: $615.00; 4866-60: $590.00.

SPECIFICATIONS-4960 ELECTROLYTIC-RESISTANCE INDICATOR

RANGE—0.3 to 30,000 ohms (working range).

LIMITS OF ERROR—±1% of reading when built-in standards keep scale reading between 0.3 and 3.

STANDARDS—Five: 1, 10, 100, 1000, and 10,000 ohms.

POWER SUPPLY—120 volts, 60 or 25 hertz.

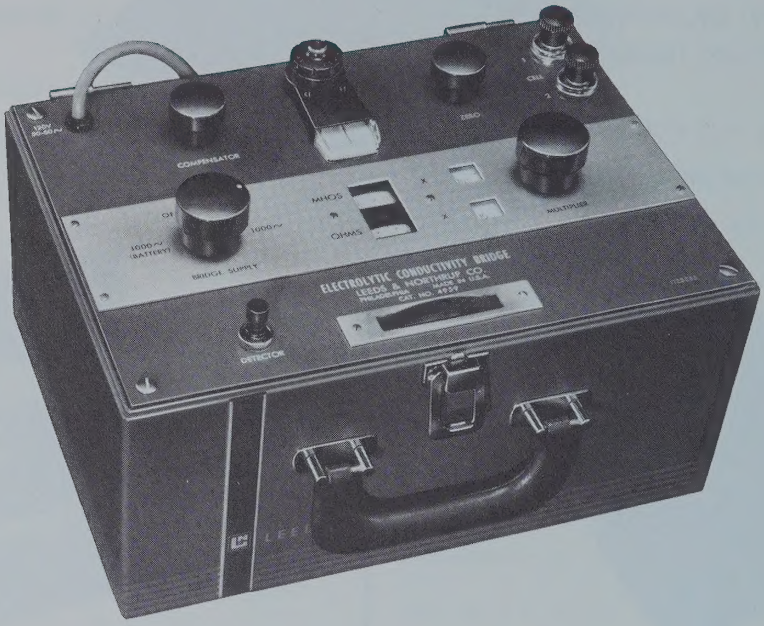
CASE—Oak, with hinged lid and carrying handle; 9½" x 6¼" x 8¼"; weight approx. 15 lb.

PRICE—$450.00.

RECOMMENDED ACCESSORIES
FOR 4866 & 4960

4917 Conductivity Cell
4920 Conductivity Cell
4805-X1 Conductivity Cell

4959 MULTI-PURPOSE ELECTROLYTIC RESISTANCE/CONDUCTANCE BRIDGE



FOR HIGH ACCURACY MEASUREMENTS FROM 0.5 TO 105,000 MICROMHOS (AND 9.5 TO 2,000,000 OHMS)

Readout in ohms and mhos

Pointer-type galvanometer

Compensation factor calculator supplied

Designed for 120 V a-c line operation

Applicable for portable or bench-top measurements, the 4959 Multi-purpose Bridge is used for high accuracy measurements over wide spans of conductance and resistance values at the process site or in the laboratory. When used with appropriate conductivity cells, it is ideally suited for measuring electrolytic conductivity or resistivity of grounded or ungrounded solutions, extending from ultra-pure demineralized water to strong acids, bases or salts. A dial provides compensation for a wide range of cell constants and solution temperatures. When properly adjusted, using the separate Compensation Factor Calculator, the instrument reads out directly in specific conductance and specific resistance.

SPECIFICATIONS

RANGES—0.5 to 105,000 micromhos; 9.5 to 2,000,000 ohms.

LIMITS OF ERROR—Mho range: ±0.15% of reading at high end of scale, increasing to ±1% of reading at 1.0 at the low end of the scale. Ohm range: ±0.15% of reading at low end of scale, increasing to ±1% of reading at 10 at the high end of the scale.

SENSITIVITY—Within 0.1% of reading.

COMPENSATOR—Allows scales to be read in specific conductance or specific resistance referred to 77 F (25 C). Range of cell-constant compensation: 0.24×10^n to 2.1×10^n where $n = 0, \pm 1, \pm 2, \pm 3$; Temperature ratio: Range 0.5 to 3.0 where Temperature Ratio =

$$\frac{\text{Measured Conductance at Solution Temperature (C or F)}}{\text{Measured Conductance at 25 C or 77 F}}$$

POWER SUPPLY—120 volts, 50/60 hertz; 3-volt self-contained battery for portable use.

CASE—Extruded aluminum with slip-hinged cover and carrying handle; 12½″ x 9″ x 7½″; weight approx. 16 lbs.

PRICE—$590.00.

RECOMMENDED ACCESSORIES

4917 Conductivity Cell, or
4920 Conductivity Cell, or
4805-☐ Conductivity Cell

E

POTENTIOMETERS AND ACCESSORIES

Introduction E-1
Potentiometers for Voltage Measurements E-8
Potentiometers for Temperature Measurements ..E-24
Potentiometer for Corrosion Potentials E-28
Volt Boxes, Shunt Boxes and Run-up Boxes E-29

POTENTIOMETERS AND ACCESSORIES

A d-c potentiometer is an adjustable calibrated source of voltage which can be used to measure unknown voltages by a direct comparison or null method. Essentially it is a resistance network of known ratios, but to perform a voltage measurement, a source of current, a reference voltage and a null detector are normally required. These are now generally incorporated in the basic potentiometer package, although traditionally they have been provided as auxiliary units.

To measure emf—or a specific quantity in terms of emf—as precisely as a given application demands, you can choose from a complete line of L&N instruments, each of which applies the most appropriate potentiometer circuitry in a thoroughly dependable construction. Each L&N potentiometer is built to give the required precision in its particular field, with maximum convenience and speed of manipulation, at a cost in keeping with its value to the user.

FACTORS IN MEASURING VOLTAGE

ADVANTAGES OF POTENTIOMETRIC NULL METHOD — The potentiometric method provides significant advantages over the use of a deflection meter or indicating amplifier to measure voltage. Negligible loading, better linearity, more stable zero and span, and greater resolution and precision are a few of the advantages of the potentiometer.

SIGNIFICANT POTENTIOMETRIC CHARACTERISTICS — Important factors in potentiometer selection are range(s), resolution (of both potentiometer and detector), and limit of error (includes both percent and residual errors).

The internal resistance of a potentiometer should be low so that insulation requirements are not severe and maximum detector sensitivity is attainable. The error due to leakage current should be minimized by guarding, and electrostatic pickup by shielding. (For a detailed description of shielding and guarding, refer to page A-19.)

A convenience feature on some potentiometers is a provision for switching and/or reversing connections to the emf source. Another is provision of selection keys with progressively increasing sensitivity for use with highly sensitive null detectors. Potentiometers for indicating temperatures in degrees should also include reference-junction compensation.

In considering ease of balance and readout, the provision of resistance decades simplifies readout, and the inclusion of slidewires facilitates following small or continuous changes. In some situations, remote readout may be desirable. The frequency with which a potentiometer must be standardized and the convenience of standardization are also important factors.

REQUIREMENTS FOR POTENTIOMETER COMPONENTS—Resistors used in potentiometers should be stable and have a low temperature coefficient. In particular, all resistors in the measuring circuit should have the same variation with temperature if an accurate voltage division is to result. Switches should have low and especially stable contact resistance, low thermoelectric emfs, high insulation resistance and long operating life with negligible attention. For a description of L&N Type 31 switches and resistors constructed of L&N Grade A manganin wire, refer to page A-18.

Slidewires should have linear characteristics, low thermoelectric emfs, and negligible wear. Keys and binding posts should be especially well-insulated and guarded, and exhibit low thermoelectric emfs.

Null detectors should have a stable zero with time and temperature, and a sensitivity consistent with the desired potentiometer resolution. In addition, they should be easily read, provide adequate discrimination against spurious signals (both differential and common mode), and be tolerant of overloads. Care must be exercised not to confuse a short full-scale range specification with high usable sensitivity. Noise levels under typical external-circuit conditions and maintenance of sensitivity under maximum expected circuit-resistance levels are also significant. In addition, one needs freedom from zero shift as the source resistance changes.

Power supplies should be stable with time and temperature, noise-free and isolated from line and ground. Voltage references (which may be part of the power supply) should also provide stability with time and temperature. For low-level or high-precision applications, both should be guarded against d-c leakage currents.

Auxiliary units which may be used with a potentiometer include a volt box for high-voltage measurements, shunts for current measurements, and a run-up box for calibration of deflection instruments.

APPLICATION

Potentiometers are used for measuring voltage, and current, temperature and other quantities which can be related to emf. The table below lists typical applications and the potentiometer characteristics which are important for each of these areas of measurement. A description of the potentiometer principle follows, along with brief descriptions of how potentiometers are used for measuring such quantities as voltage, current, temperature, and resistance. A selection guide (based on range and accuracy) for potentiometers used for current, voltage and temperature measurements is provided at the end of this introduction to assist you in quickly locating the instrument best suited to your particular application. Detailed descriptions, specifications, and illustrations of all L&N potentiometers appear on the following pages. This chapter also provides application data and information on L&N volt boxes, shunt boxes and run-up boxes.

Measurement Area	Typical Applications	Characteristics & Requirements
Voltage	Calibration of other d-c instruments Measurement of voltages in electronic circuits Calibration of standard cells Measuring Zener-diode voltages Measurements with transducers which convert to voltage Determining corrosion potentials	High precision, and resolution Guarding required for high-resistance sources and/or high-humidity conditions Volt box required for high voltages Run-up box may be required for calibration
Current	Measurement of electro-magnet current Testing Zener-diode currents Measuring resistance-thermometer current Wattage dissipation of d-c heaters	Multi-range shunts for low and medium currents Single shunt for very high currents Self-heating of shunt may be significant
Temperature	Calibration of temperature-measuring equipment Measurements of temperature (with thermocouple or resistance thermometer and auxiliary equipment) Output of optical or radiation pyrometers	Reference-junction compensation desirable Direct readout in temperature convenient May read R_t / R_0 of the resistance thermometer

THE POTENTIOMETER PRINCIPLE

The potentiometer is an instrument for measuring an emf or potential difference by comparing it with an accurately known potential drop. It may be used directly for measurement of voltage, or, by measuring the voltage drop across a shunt of known resistance, can also serve to determine current.

In its most basic form, a potentiometer is simply a uniform resistance wire aligned along a scale graduated in uniform divisions, with a sliding contact on the wire. A cell or battery is connected to provide a flow of working current.

Figure 1 illustrates how a simple potentiometer is used to measure emf. An unknown emf is connected in series with a null detector and in series opposition with the voltage drop produced by the working current in the uniform wire. No current will flow through the null detector if the contact is adjusted to such a position that the voltage drop from the contact to the "minus" terminal is exactly equal to the unknown emf. Thus, two potential differences are opposed so that one exactly counterbalances the other and a sensitive current-indicating instrument such as an electronic null detector shows when such a condition of balance exists. This is the null-balance method of measurement. Note particularly that, at balance, no current is drawn from the voltage source being measured.

The accuracy of the potentiometer method depends primarily on the uniformity of the calibrated wire (or other means of voltage division) and the accuracy of the potentiometer current. The potentiometer current is established by impressing a standard cell across the known resistance of the potentiometer circuit, and adjusting the "adjustable resistance" (Figure 2) until the null detector indicates a balance. The uniformity of the wire or potential divider is a function of its design and construction.

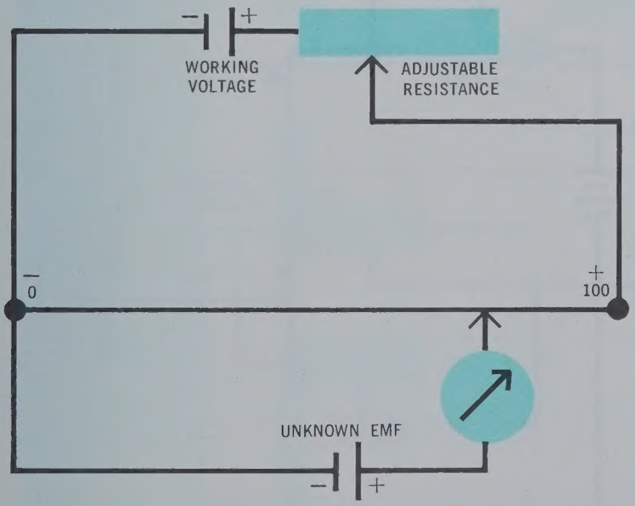


FIG. 1 Potentiometer Circuit

MEASURING VOLTAGE AND CURRENT

Potentiometers are used for voltage and current measurements where the precision required is higher than that which can be obtained by deflection-type instruments or d-c indicating amplifiers.

A great advantage is that the current drawn from the source under measurement is held to an extremely small value . . . approaching zero at balance.

Figure 2 shows an arrangement for measuring voltage or current. To measure voltages beyond the range of the potentiometer, an emf measurement is made by connecting the unknown source to the potentiometer through a volt box. Current is measured by using the potentiometer to measure the voltage drop produced by the flow of the unknown current through a precise, known resistance provided by a shunt box. The unknown voltage or current may be determined by multiplying the reading on the potentiometer by the multiplier on the volt box or the shunt.

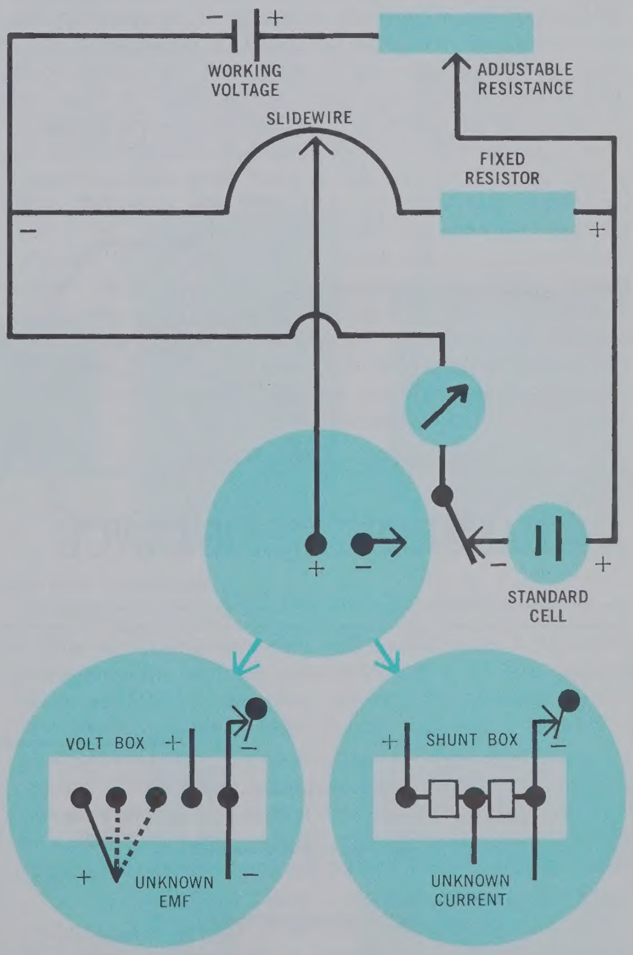


FIG. 2 Measuring Voltage and Current

MEASURING TEMPERATURE WITH THERMOCOUPLES

There is a direct relationship between the difference in the temperature of the junctions of a thermoelectric circuit and the resultant emf in that circuit. By measuring this emf with a potentiometer, the difference in temperature between the measuring junction and the reference junction of the circuit can be determined. If the reference-junction temperature is known, then the temperature of the measuring junction can be determined. The temperature sensing device, or thermocouple, is formed of wires of two dissimilar metals. Thermocouple temperature measurements are actually a measurement of temperature difference between the "hot" or measuring junction, and the "cold" or reference junction.

As shown in Figure 3, the emf is measured by adjusting the slidewire until the known emf matches the emf signal from the thermocouple to obtain a null balance on the detector. At this point, the unknown emf is equal to the voltage drop across that portion of the adjustable arm which is matched against the unknown emf.

Because the emf produced by a thermocouple is a function of the difference in temperature between the measuring and reference junctions, a dependable temperature-millivoltage relationship can be established only if the reference-junction temperature is fixed, or if proper compensation is provided. For precise temperature measurements, the reference junction is maintained in an ice-bath to provide a fixed temperature. Potentiometers calibrated in millivolts are provided with manual reference junction compensation.

Potentiometers calibrated in degrees for a specific thermocouple provide automatic compensation by means of a fixed resistor which has a temperature-resistance relationship similar to the temperature-emf relationship of the thermocouple. Where temperature differences or gradients are of interest, compensation is not required since both junctions are active.

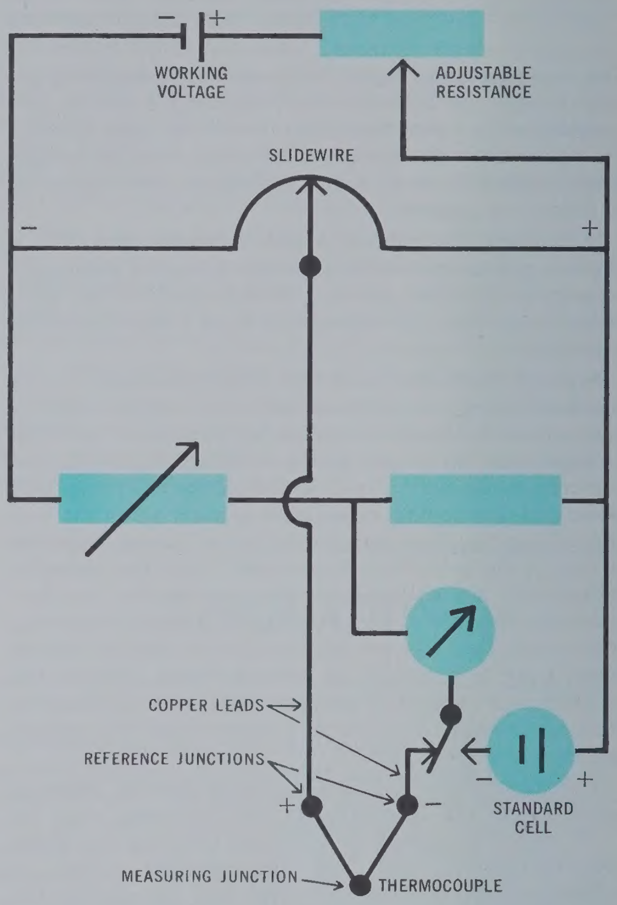


FIG. 3 Measuring Temperature

MEASURING RESISTANCE

Although it is convenient to measure resistance with a bridge, use of a potentiometer can be advantageous where current through the unknown resistance is of interest or where four-lead resistance values are wanted.

Figure 4 illustrates a circuit using a potentiometer and a standard resistance to measure an unknown resistance. If in this circuit we establish a known current I by measuring the voltage drop across the standard resistance, and then measure the voltage across the unknown resistance E, the unknown resistance is equal to: $R=E/I$.

The relationship between the unknown and standard resistance may be expressed in the equation $X/S=E_x/E_s$ where X and S are the unknown and standard and E_x and E_s are the potential drop across the unknown and standard resistance respectively. Thus the unknown resistance may be calculated from: $X=S(E_x/E_s)$.

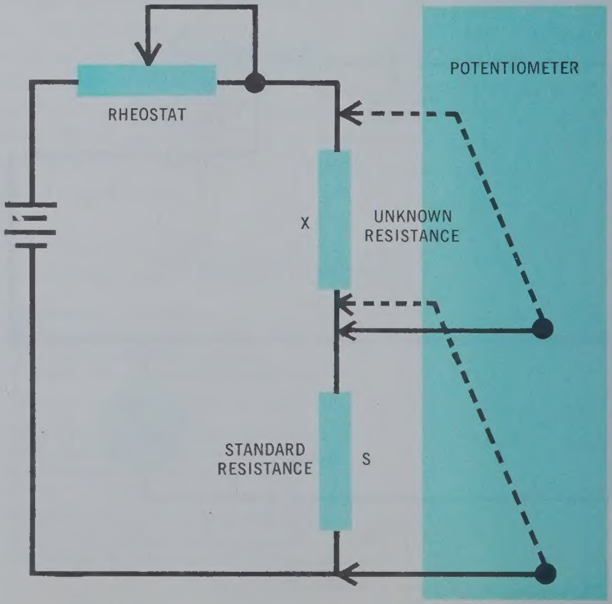


FIG. 4 Resistance Measurement by Potentiometer Method

CALIBRATING A VOLTMETER WITH A POTENTIOMETER & VOLT BOX

Voltages within the range of the potentiometer are measured by direct comparison with the voltage drop across the calibrated resistance within the potentiometer, without drawing current from the unknown. Higher potentials require a potential divider network, so that the potentiometer measures a definite fraction of the unknown. The potential divider, or volt box, draws current from the measured source, so that the null-current feature of the usual potentiometer measurement is lost; however, the current drain of the volt box may be of no significance.

One use of a volt box is the calibration of a d-c voltmeter. Figure 5 illustrates a method of accomplishing this. In checking the calibration of the voltmeter, the volt box is set to the desired range, and the applied voltage is adjusted by means of the rheostats across the d-c supply to give the desired reading on the voltmeter. When the desired voltmeter reading is obtained, the potentiometer is balanced, and, applying the multiplier value for the volt box, the true voltage across the voltmeter is read. The error may be tabulated, or the meter adjusted to read correctly at this point. For this application the loading effect of the volt box is not a factor.

CALIBRATING A D-C AMMETER WITH A POTENTIOMETER & SHUNT

Figure 6 illustrates a circuit used for calibrating a d-c ammeter. The potentiometer is designed primarily to measure voltage, but by applying Ohm's Law, the current in a circuit may also be measured with a potentiometer. That is, knowing the precise value of a resistance and the precise voltage measured across it, the current which produced this voltage drop can be determined.

The standard current-shunt resistor selected must be able to carry the current measured and be of such resistance that the voltage drop can be measured on the potentiometer. Standard shunts are provided with four binding posts, two heavy ones for current connections and two lighter ones for measuring the potential drop, and are available for current ranges of microamperes to thousands of amperes.

Knowing the resistance of the standard shunt and the voltage across it, we may calculate the current through it. By converting the reading on the potentiometer to current, the ammeter reading may be checked.

A shunt box may also be used in place of the standard shunt shown. This has the advantage of being adjustable, permitting a wide range of current measurements.

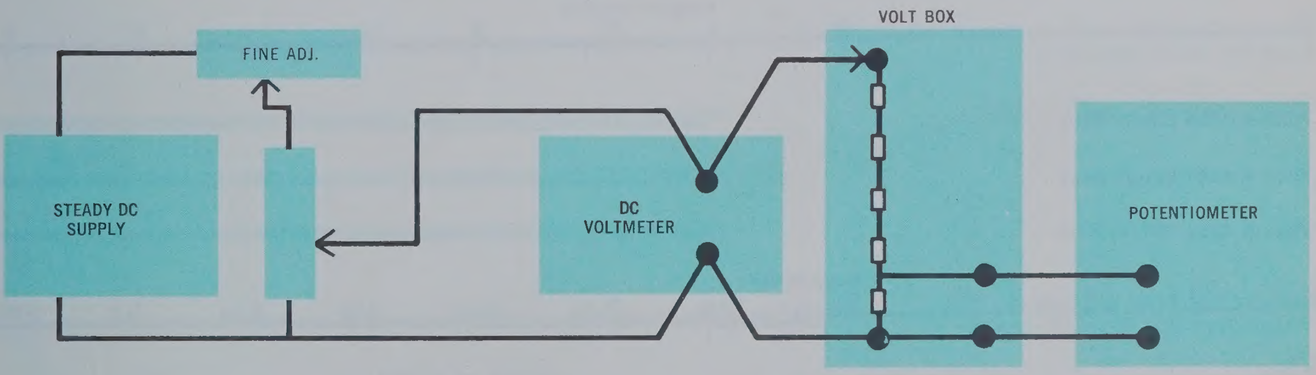


FIG. 5 Calibration of a Voltmeter by a Potentiometer

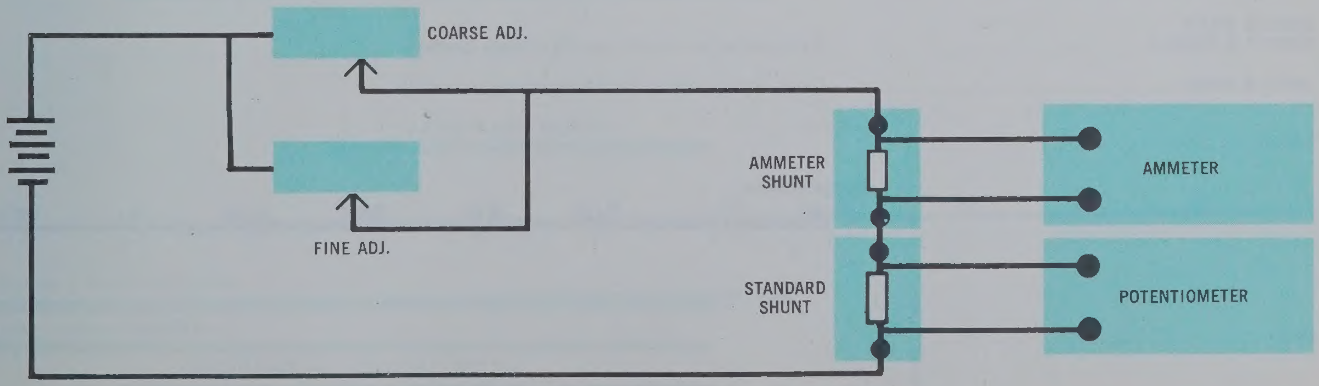
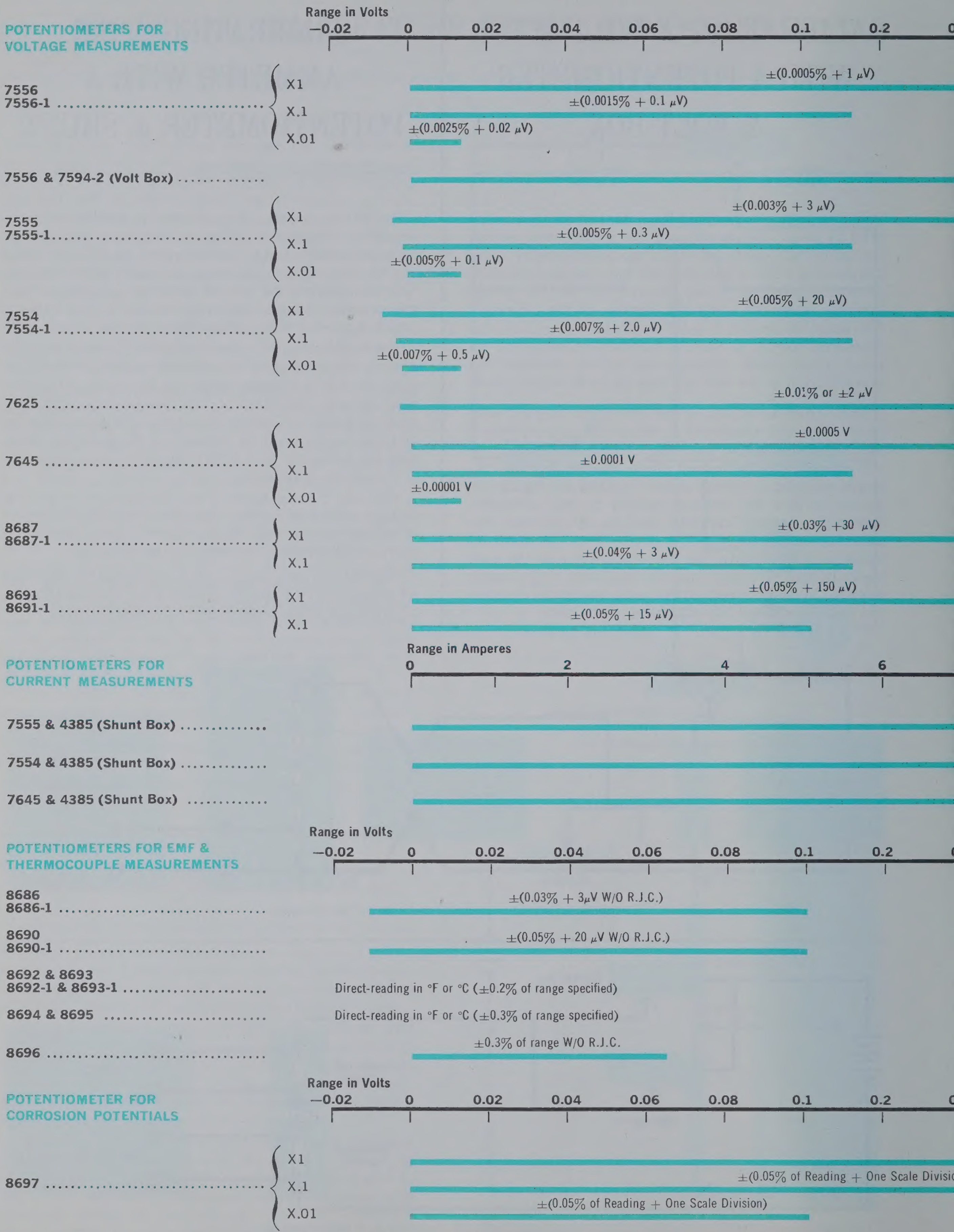


FIG. 6 Calibration of a DC Ammeter by a Potentiometer

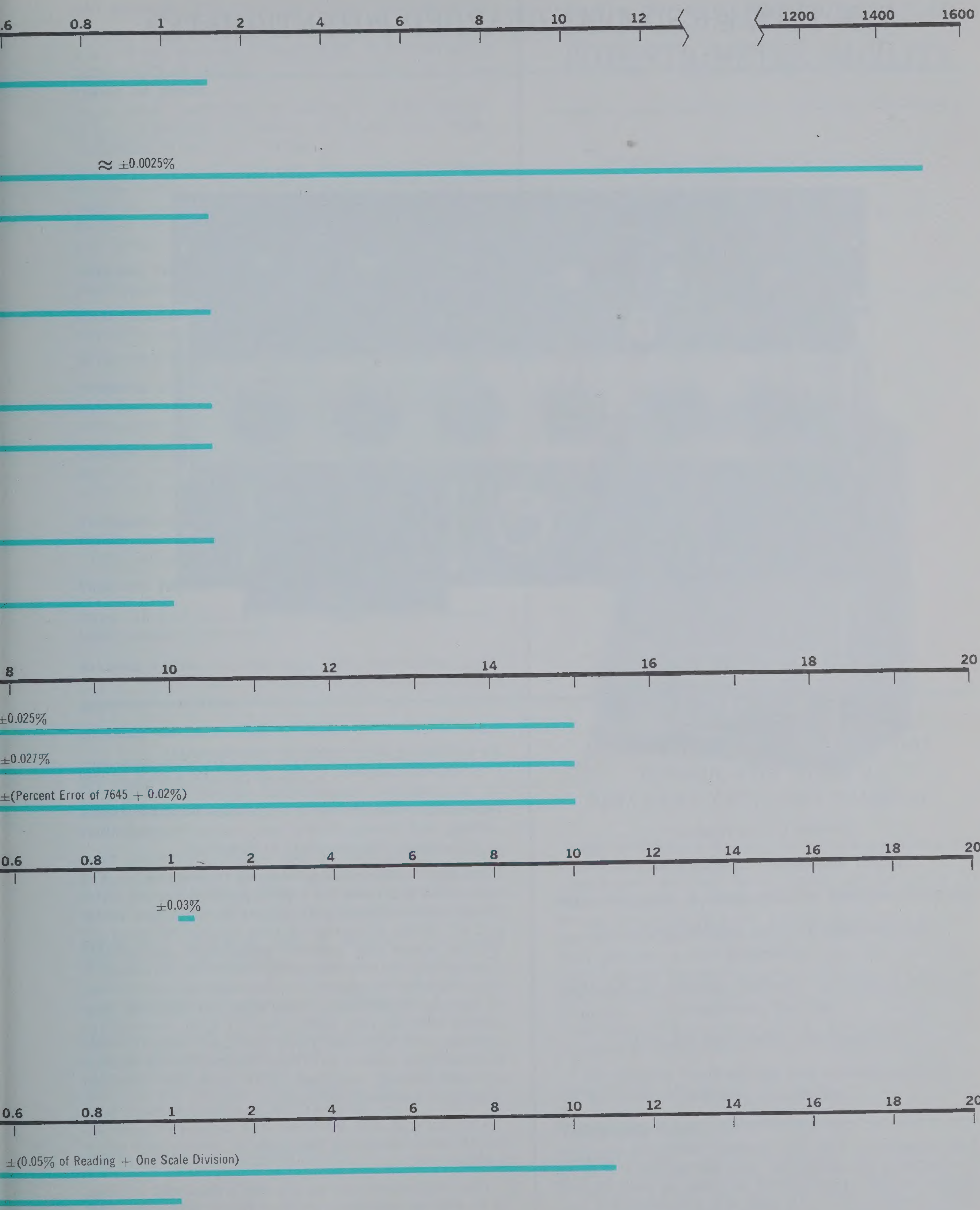
SELECTION GUIDE—L&N D-C POTENTIOMETERS

RANGES AND LIMITS OF ERROR* *(Stated accuracies shown are without L&N Report of Calibration; hig*

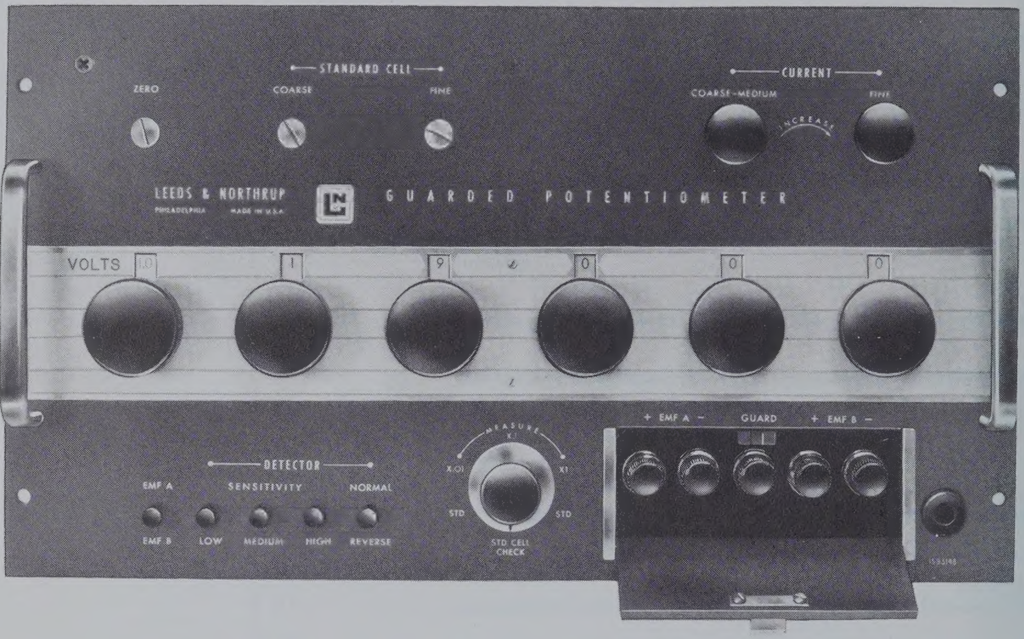


* *Unless otherwise specified, all limits of error are in terms of percent of reading.*
Note: "–1" suffix indicates rack-mounted instrument.

curacies are attainable with certification.)



7556 TYPE K-6 SIX-DIAL GUARDED POTENTIOMETER


STANDARD CELL
ZERO
COARSE
FINE
CURRENT
COARSE-MEDIUM
INCREASE
FINE
LEEDS & NORTHRUP
PHILADELPHIA
MADE IN U.S.A.
GUARDED POTENTIOMETER
VOLTS
DETECTOR
EMF A
SENSITIVITY
NORMAL
EMF B
LOW
MEDIUM
HIGH
REVERSE
MEASURE
X.01
X1
STD
STD
STD CELL CHECK
+ EMF A −
GUARD
+ EMF B −

TRIPLE-RANGE MEASUREMENTS TO 1.6 VOLTS WITH HIGHEST ACCURACY PRESENTLY AVAILABLE

Six-dial in-line readout

Type 31 enclosed silver-alloy switches

Matched resistors of L&N grade A manganin wire

Metal case and top plate provide electrostatic shielding

Thermal-equalizing chamber houses all resistors, key and switches

Provision for measuring two emfs

Battery, detector and standard-cell circuits are individually guarded

The three-range 7556 Potentiometer meets the exacting requirements of calibration laboratories for a precise voltage-measuring instrument that may be used for emf measurements up to 1500 volts with a suitable volt box, for standard-cell checking and calibration, for measuring resistances by comparison or by IR-drop methods, and for calibrating other precision potentiometers.

In R&D laboratories, it may be used for a wide variety of d-c potential measurements as well as for precise temperature measurements in studies of specific heats, melting and boiling points, etc., using thermocouples and resistance thermometers as detectors.

Among the many design features incorporated in this instrument to provide the highest possible accuracy are: construction of all critical resistors from a single length of L&N Grade A manganin wire to provide minimum resistor aging and uniform temperature coefficients; guarded circuits and electrostatic shielding; all resistors, keys and switches housed in a thermally-lagged chamber to assure temperature uniformity; standard-cell and battery controls with better than 0.1 ppm resolution of settings; and high-quality enclosed L&N Type 31 silver-alloy switches used in all critical decades. In-line readout provided through windows above each dial simplifies reading of measured variables.

Two pairs of emf terminals and associated selector switch allow measuring two emfs, or polarity reversal of a single emf.

This instrument can supply the critical dial settings to an external readout or printing device (add suffix "-R" to List No. for this feature). An L&N Report of Calibration is available as an option (add suffix "-B").

SPECIFICATIONS

LIST NUMBERS—7556 (bench top); 7556-1 (rack-mounting)

RANGES—Three: 0 to 1.6 volts in steps of 1.0 μV (X1); 0 to 0.16 volt in steps of 0.1 μV (X0.1); 0 to 0.016 volt in steps of 0.01 μV (X0.01).

LIMITS OF ERROR—
High range: ±(0.0005% of reading + 1μV); Medium range: ±(0.0015% of reading + 0.1μV); Low range: ±(0.0025% of reading + 0.02 μV).

With L&N Report of Calibration: Using corrections shown on this certificate the limits or error at 25 C become: High Range (X1): ±(0.0003% of reading + 0.5μV); Medium Range (X.1): ±(0.0010% of reading + 0.05μV); Low Range (X.01): ±(0.0015% of reading + 0.01 μV).

THERMAL EMF—Less than 0.1 μV thermal emf, of very short duration, is developed during operation of switches.

ZERO TRIMMER—For convenience in balancing residuals. Resolution is better than 0.1 ppm.

DETECTOR KEYS—Three tap keys.

INTERNAL RESISTANCE—Resistance of potentiometer as seen from source of unknown emf varies from 10 to 220 ohms, depending upon dial setting.

CURRENT STANDARDIZATION—Provided by one "Coarse-Medium" knob and one ten-turn "Fine" knob. Resolution is better than 0.1 ppm.

STANDARD-CELL ADJUSTMENTS—Utilizes main potentiometer dials to set standard-cell value. "Coarse" and "Fine" adjustments. Resolution is better than 0.1 ppm.

FUNCTION SWITCH—For standardizing and range selection.

KEYS—All keys have gold contacts and are of thermal-free, guarded construction.

BINDING POSTS—Guarded type with low-thermal, gold-plated copper terminals and acrylonitrile-polystyrene copolymer insulation.

GUARDED CIRCUITS—Battery, standard cell and detector.

CHECKING FACILITIES—All necessary check points (eight) are brought out to rear terminals.

POWER REQUIREMENTS—11 mA, from 1.8 to 2.16 volts d-c supply.

CASE—Metal, with hinged door on front plate for access to input terminals. 7556 (for bench top use): 19-9/32″ (w) x 10¾″ (h) x 7-5/16″ (d); 7556-1 (for mounting in 19″ relay rack): x 10-15/32″ (h) x 7½″ (d); weight approx. 32 lb.

PRICE—7556: $3200.00; 7556-1: $3150.00; "-B" add $250.00; "-R" add $200.00.

RECOMMENDED ACCESSORIES

9878 Guarded D-C Constant Voltage Supply
7308 Unsaturated Standard Cell, or
7311 Saturated Cell Assembly
9834 Guarded Electronic Null Detector, or
9838 Guarded Electronic Null Detector

OPTIONAL ACCESSORIES

127272 Bracket (for 7556)
7582, 7592, 7593 Volt Box, or
7594, 7594-2 Volt Box
4385 Shunt Box

7556-A □ SIX-DIAL GUARDED POTENTIOMETER FACILITY

Completely packaged and pre-wired with matched components

Guarded construction minimizes effect of stray leakage

These facilities are designed to provide pre-wired, permanently interconnected, compatible components to complement the 7556 Potentiometer and to assure the maximum accuracy and precision which it is capable of providing. The 7556-A11 Facility consists of a 7556-1 Six-dial Guarded Potentiometer, a 9834-1 Guarded D-C Null Detector, a 7308 Unsaturated Standard Cell, and a 7597 Two-volt Storage Cell; the 7556-A12 is the same as the -A11 except a 9878 Guarded D-C Constant-Voltage Supply is substituted for the Two-volt Storage Cell. The 7556-A13 is the same as the -A12 except a 9838-1 Guarded D-C Null Detector is substituted for the 9834-1.

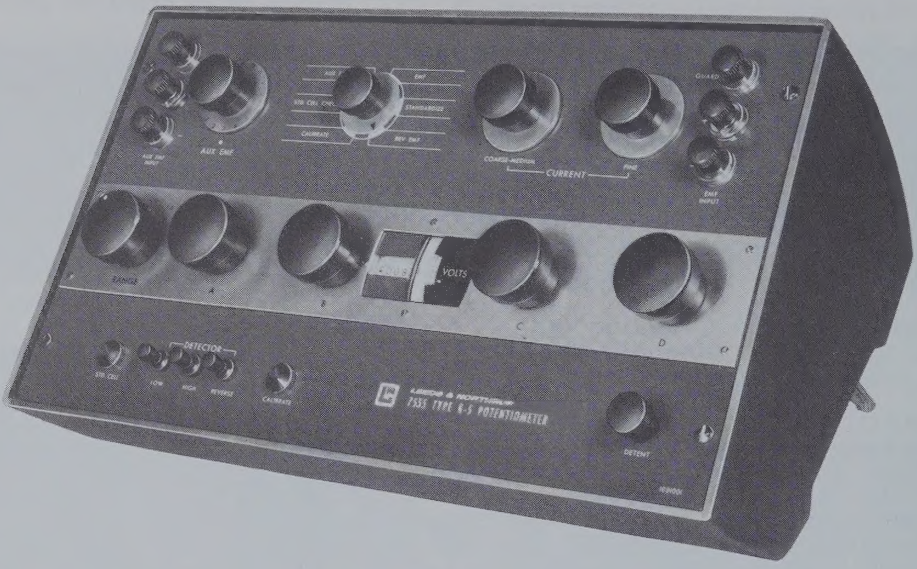
SPECIFICATIONS

LINE POWER INPUT—107-127 V, 60-50 Hz.

CABINET—Metal, finished in durable, light gray baked enamel, with lifting handles; 22-3/16″ (w) x 27-3/16″ (h) x 19″ (d); weight 125 lbs; vinyl dust cover included.

PRICE—7556-A11: $3875.00; 7556-A12: $4225.00; 7556-A13: $4780.00; "-R" add $200.00.

7555 TYPE K-5 UNIVERSAL GUARDED POTENTIOMETER



HIGH-PRECISION MEASUREMENTS OVER THREE RANGES UP TO 1.6 VOLTS

Central readout window with decimal automatically positioned

Three type 31 switches and slidewire

Thermal and electrostatic shielding

Completely guarded construction

Cast aluminum case with retractable legs

A direct-reading, high-precision potentiometer designed for multi-purpose laboratory use, the Type K-5 Potentiometer provides new convenience and capability for potentiometric measurements of current, resistance, energy and other related emfs. The K-5 is especially useful for precise temperature measurements in studies of specific heats, melting and boiling points, etc. (using thermocouples and resistance thermometers); for standard-cell checking and calibration; for measuring resistance by comparison; for calibrating less precise potentiometers, as well as for precise measurements in a wide variety of applications such as calorimetry, cryogenics, pH studies, and electrical potentials from a wide variety of electrodes, transducers, and sensors.

Features include five-decade operation over three ranges, totally-enclosed L&N Type 31 switches with special brush-and-contact arrangements for high stability of contact resistance, direct readout in a central window with automatic positioning of decimal, shielded and guarded construction, a double slidewire contact for thermal cancellation, and a function switch with polarity reversal and calibration provisions. A stable live zero is provided through internal lead balance, and small continuous changes may be easily followed. The instrument has a resolution of 0.02 μV/division on low range. An optional L&N Report of Calibration is available (suffix "-B").

The bench-top instrument is supplied in a newly-designed cast aluminum case provided with retractable legs and rubber feet. With legs retracted, the faceplate angle is about 30°, for use by a standing operator; with legs extended, the angle is increased to about 50° for greater convenience for a seated operator.

SPECIFICATIONS

LIST NUMBERS—7555 (bench-top); 7555-1 (rack-mounting).

RANGES—High: $-50\ \mu$V to $+1.611\,050$ volts; Middle: $-5\ \mu$V to $+0.161\,105\,0$ volt; Low: $-0.5\ \mu$V to $\pm 0.016\,110\,50$ volt.

LIMITS OF ERROR—Standard: High Range (1.6)*: $\pm$(0.003% of reading $+ 3\ \mu$V); Middle Range (0.16)*: $\pm$(0.005% of reading $+ 0.3\ \mu$V); Low Range (0.016): $\pm$(0.005% of reading $+ 0.1\ \mu$V).

**For "A" dial settings other than zero on 1.6 and 0.16 ranges.*

With L&N Report of Calibration: Using corrections shown on this certificate the limits of error at 25 C become: High Range (1.6): ±(0.001% of reading + 2 μV); Middle Range (0.16): ±(0.003% of reading + 0.2 μV); Low Range (0.016): ±(0.003% of reading + 0.1 μV).

MEASURING DIALS—Voltages shown are for high range: "A" Switch: 16-position rotary switch, 0 to 1.5 volts: "B" Switch: 11-position rotary switch, 0 to 0.1 volt: "C" Switch: 11-position rotary switch, 0 to 0.01 volt; "D" Slidewire: one turn, with range of −50 to +1050 μV, positive mechanical stops. Detent gives 110 discrete steps of 10 μV per step (550 divisions of 2 μV per division).

THERMAL EMF—Transient thermals are less than 0.1 μV during normal operation of switch; less than 0.1 μV within one second after normal operation of slidewire.

DETECTOR KEYS—Three, low-thermal.

INTERNAL RESISTANCE—Varies from approximately 10 to 280 ohms (depending on dial settings), measured across emf input terminals.

POWER REQUIREMENTS—12.1 mA, from 1.8 to 2.2-volt d-c supply.

CURRENT STANDARDIZATION—With one coarse-medium rheostat and one ten-turn fine rheostat. Resolution is better than 0.5 ppm.

STANDARD-CELL ADJUSTMENT—Value is set on main dials, to better than 0.3 ppm resolution when SC is in the range of 1.0175 to 1.0205 volts.

FUNCTION SWITCH—Rotary-type, provides choice of six settings.

RANGE SWITCH—Permits selection of three ranges: 1.6 (high), 0.16 (middle) and 0.016 (low).

BINDING POSTS—Guarded-type, low-thermal, gold-plated copper terminals with acrylonitrile-styrene copolymer insulation.

AUXILIARY EMF CIRCUIT—Input terminals and 16-position rotary switch (steps equal to "A" switch) for current, resistance, energy and other measurements of different but related emfs (e.g. wattmeter calibration).

GUARDED CIRCUITS—Detector, standard cell and power supply circuits.

SELF-CALIBRATION FEATURES—Potentiometer zero and relationship of "B" dial to "A" dial may be precisely checked and readjusted by user.

CASE—7555 has cast aluminum case and vinyl dust cover; 7555-1 has sheet-metal case. Durable gray finish. Rack-mounting: 19″ (w) x 10-15/32″ (h) x 8½″ (d) behind panel; weight approx. 22 lb. Bench-top: 19¼″ (w) x 11″ (h) x 9½″ (d) 11⅜″ deep with legs extended; weight approx. 33 lb.

PRICE—7555 and 7555-1: $975.00; "-B", add $200.00.

RECOMMENDED ACCESSORIES

9878 Power Supply
7308 Standard Cell, or
7311 Saturated Cell Assembly
9834 Null Detector

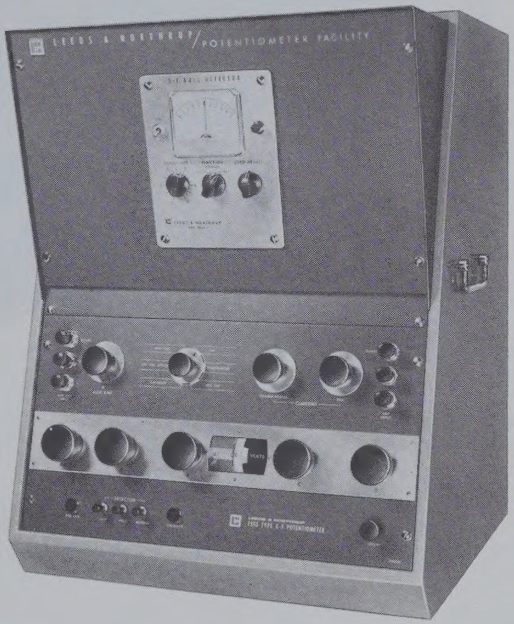
OPTIONAL ACCESSORIES

7582, 7592, 7593 Volt Box
4385 Shunt Box

7555-A ☐ TYPE K-5 POTENTIOMETER FACILITY

Completely packaged and pre-wired with matched components

Guarded construction minimizes effect of stray leakage


LEEDS & NORTHRUP / POTENTIOMETER FACILITY
LEEDS & NORTHRUP
7555 TYPE K-5 POTENTIOMETER

The K-5 Potentiometer is available in two completely packaged facilities containing pre-wired compatible components. The 7555-A10 consists of a 7555-1 Potentiometer, a 9834-1 Null Detector, a 7308 Unsaturated Standard Cell and a 7597 Two-volt Storage Cell. The 7555-A12 consists of the same components as the 7555-A10 except a 9878 Power Supply replaces the two-volt cell.

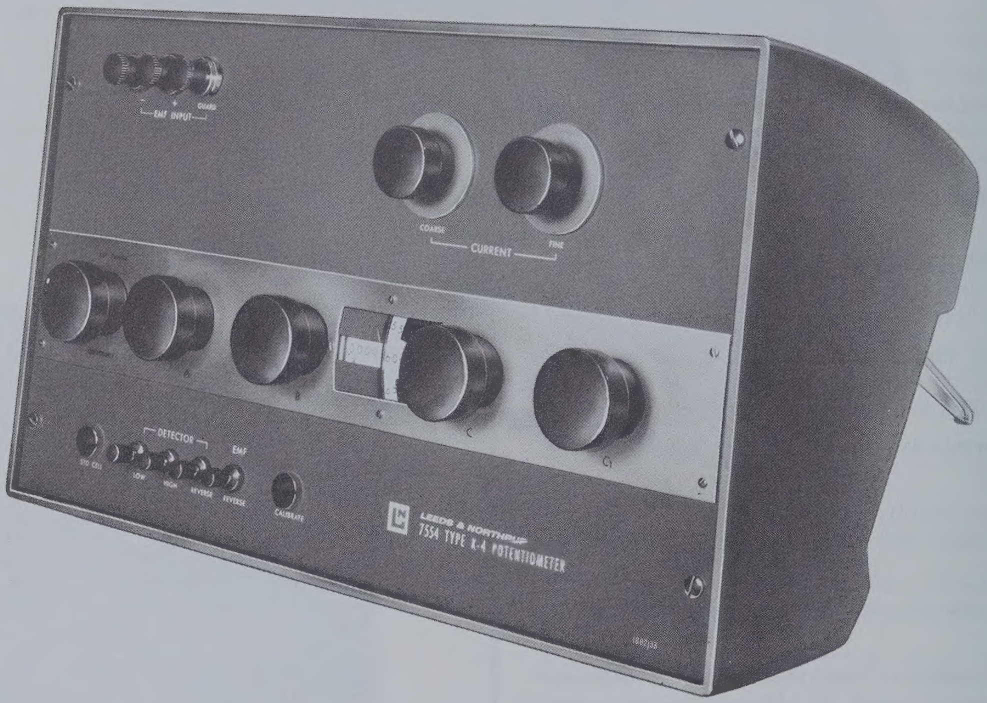
SPECIFICATIONS

LINE POWER INPUT—107 to 127 volts, 60/50 Hz.

CABINET—Metal, light gray finish, with lifting handles, vinyl dust cover included: 22-3/16″ (w) x 27-3/16″ (h) x 18-5/16″ (d); weight approx. 110 lb.

PRICE—7555-A10: $1695.00; 7555-A12: $2045.00.

7554 TYPE K-4 UNIVERSAL GUARDED POTENTIOMETER



PRECISION MEASUREMENTS OVER THREE RANGES UP TO 1.6 VOLTS

Central readout window with decimal automatically positioned

Three type 31 switches and slidewire

Thermal and electrostatic shielding

Completely guarded construction

Cast aluminum case with retractable legs

A direct-reading, precision potentiometer, the Type K-4 Potentiometer provides improved accuracy with new convenience and capability for a variety of potentiometric measurements. The K-4 features L&N Type 31 switches, advanced circuitry, completely guarded construction, thermal and electrostatic shielding, and provision for convenient self-calibration. The instrument is electrically balanced for stable live zero, and permits small continuous changes to be easily followed.

Resolution is 0.5 μV/division on low range. A centralized display of numerical values provides direct readability to four or five digits (estimated sixth), and provides automatic positioning of the decimal point. An L&N Report of Calibration is available as an extra-cost option (suffix "-B").

The bench-top model is available in a new cast-aluminum case with retractable legs. With legs retracted, faceplate angle is about 30° with the horizontal for convenient operation in a standing position; with legs extended, 50° angle provides maximum convenience for a seated operator.

SPECIFICATIONS

LIST NUMBERS—7554 (bench-top); 7554-1 (rack-mounting).

RANGES—High: −500 μV to +1.610 50 volts; Middle: −50 μV to +0.161 050 volt; Low: −5 μV to +0.0161050 volt.

LIMITS OF ERROR—Standard: High Range (1.6): ±(0.005% of reading + 20 μV); Middle Range (0.16): ±(0.007% of reading + 2.0 μV); Low Range (0.016): ±(0.007% of reading + 0.5 μV).

With L&N Report of Calibration*: High Range (1.6): ±(0.002% of reading + 20 μV); Middle Range (0.16): ±(0.005% of reading + 2.0 μV); Low Range (0.016): ±(0.005% of reading + 0.5 μV).

MEASURING DIALS—Voltages shown are for high range: "A" Switch (16-position rotary switch): 0 to 1.5 volts; "B" Switch: 11-position rotary switch, 0 to 0.1 volt; "C" Slidewire: one turn, with range of −500 μV to +0.0105 volt.

THERMAL EMF—Transient thermals are less than 0.1 μV during normal operation of switch; less than 0.3 μV within one second after normal operation of slidewire.

REVERSE EMF KEY—Low-thermal lock-down type, reverses connections to the emf being measured.

DETECTOR KEYS—Three, low-thermal.

INTERNAL RESISTANCE—Varies from approximately 10 to 280 ohms (depending on dial settings), measured across emf terminals.

POWER REQUIREMENTS—12.1 mA, from 1.8 to 2.2-volt d-c supply.

CURRENT STANDARDIZATION—With one ten-turn "Coarse" rheostat and one ten-turn "Fine" rheostat. Resolution is better than 4.0 ppm.

STANDARD-CELL ADJUSTMENT—Value of standard cell (within the range of 1.0175 to 1.0205 volts) is set on main dials. Resolution is better than 8.0 ppm.

FUNCTION SWITCH—Rotary-type, choice of six settings.

GUARDED CIRCUITS—Detector, standard cell and power supply circuits.

BINDING POSTS—Guarded-type, low-thermal, gold-plated copper terminals with acrylonitrile-styrene copolymer insulation.

SELF-CALIBRATION FEATURES—Potentiometer zero and relationship of "B" dial to "A" may be precisely checked and readjusted if necessary.

CASE—7554 has cast aluminum case and vinyl dust cover; 19¼″ (w) x 11″ (h) x 9½″ (d) (11⅜″ with legs extended); weight approx. 32 lbs. 7554-1 has sheet-metal case; 19″ (w) x 10-15/32″ (h) x 8½″ (d) behind panel; weight approx. 21 lbs.

PRICE—7554 and 7554-1: $675.00; "-B" add $150.00.

RECOMMENDED ACCESSORIES

9834 Null Detector, or
2430-A Galvanometer, or
Type HS Galvanometer
7308 Unsaturated Standard Cell, or
7311 Saturated Standard-Cell Assembly
9879 Constant-Voltage Supply

OPTIONAL ACCESSORIES

7582, 7592, 7593 Volt Box
4385 Shunt Box

**Furnishes correction data at 25 C for improved limits of error.*

7554-A □ TYPE K-4 POTENTIOMETER FACILITY

Completely packaged and pre-wired with matched components

Guarded construction minimizes effect of stray leakage

The K-4 Potentiometer is available in two completely packaged, pre-wired facilities consisting of precision components selected for compatibility in performance and specifications. The 7554-A10 consists of a 7554-1 Type K-4 Potentiometer, a 9834-1 Null Detector, a 7308 Unsaturated Standard Cell, and a 7597 Two-volt Storage Cell. The 7554-A11 consists of the same components as the 7554-A10 except a 9879 Guarded D-C Constant-Voltage Supply replaces the storage cell.

SPECIFICATIONS

LINE POWER INPUT—107 to 127 volts, 60/50 hz.

CABINET—Metal, light gray finish, with lifting handles, vinyl dust cover included; 22-3/16″ (w) x 27-3/16″ (h) x 18-5/16″ (d); weight approx. 110 lb.

PRICE—7554-A10: $1395.00; 7554-A11: $1495.00.

7625 BROOKS-HARRIS POTENTIOMETER

FOR HIGHLY PRECISE MEASUREMENTS
FROM −10 MICROVOLTS
TO +1.611 10 VOLTS

Developed according to N B S specifications

Special electrostatic and thermal shielding

Thermally-insulated box houses critical circuit elements

Potentiometer sections can be used independently

The Brooks-Harris Potentiometer is a high-precision, high-accuracy instrument designed to facilitate the routine d-c certification of wattmeters, voltmeters, ammeters and attenuators. Developed according to N B S specifications, it consists of three potentiometers connected in series: the first two (wide and intermediate range) are each two-dial, conventional constant-current units; the third (narrow range) is a Lindeck constant-resistance potentiometer with a meter readout device. The metal top plate and metal case lined with balsa wood provide electrostatic shielding and thermal equalization. This potentiometer can be read to six (estimated seven) significant figures.

SPECIFICATIONS

RANGE— −10 μV to +1.6111 volts.

READOUT—Wide-range potentiometer consists of two switches of 15 (X0.1) volt and 10 (X0.01) volt; second potentiometer consists of two switches of 10 (X0.001) volt and 10 (X0.0001) volt; third potentiometer is a Lindeck element with switch providing range multipliers of X1, X10, and X100. Meter is calibrated from −10 to +110 μV in steps of 0.5 μV and can be estimated to the nearest 0.1 μV.

LIMIT OF ERROR—±0.01% of reading or 2 μV, whichever is larger.

THERMAL VOLTAGES—When all three potentiometers are used, internal thermal voltages will not exceed 1 μV; when only intermediate and narrow-range potentiometers are used, internal thermal voltages will not exceed 0.1 μV.

AUXILIARY EMF SWITCHES—Two switches, one calibrated 0 to 15 in steps of 0.1 volt and the other calibrated 0 to 9 (plus one step marked X to represent 10) in steps of 0.01 volt.

CASE—Aluminum case and top plate lined with balsa wood; carrying handles provided; 26″ x 19″ x 8″; weight approx. 35 lb.

PRICE—$8000.00.

RECOMMENDED ACCESSORIES

9834 D-C Null Detector
2435-C Galvanometer
7597 Battery
Std 2233 Battery (2)
7309 Standard Cells (2)

7645 STUDENTS' POTENTIOMETER

TRIPLE-RANGE MEASUREMENTS TO 1.6 VOLTS WITH HIGH ACCURACY

Designed to demonstrate potentiometer principle

L&N type 31 enclosed silver-alloy switch

Provision for use of slidewire as ratio arms of Wheatstone-bridge circuit

Metal case and top plate provide electrostatic shielding

This triple-range Students' Potentiometer offers many outstanding features which educators consider highly desirable in an instrument designed to demonstrate the potentiometer principle. In addition, it provides accuracy necessary for investigational work and instrument calibration. Design features include: a central reading window in which the measured emf appears as a row of digits plus a scale interpolation; high-quality L&N Type 31 Selector Switches which assure low, stable contact resistances and low thermal emfs; extra binding posts and end coils so that the slidewire may be used as the ratio arms of a Wheatstone-bridge circuit.

Three ranges permit a variety of applications: high range for measurements of emf of cells for pH or redox; medium range for measurements exceeding the maximum range of the potentiometer (with shunts or volt boxes); and low range for temperature measurements with thermocouples. Rugged construction assures reliable service even when used by novices in laboratory techniques.

SPECIFICATIONS

RANGES—0 to 1.6 volts; 0 to 0.16 volt; 0 to 0.016 volt.

LIMITS OF ERROR—High Range: ±0.0005 volt; Medium Range: ±0.0001 volt; Low Range: ±0.000 01 volt.

SLIDEWIRE—Smallest scale divisions: high range, 500 μV, resolution 100 μV; medium range, 50 μV, resolution 10 μV; low range, 5 μV; resolution 1 μV. Scale has 200 divisions, calibrated 0 to 100. Uniformity of scale is within ±1 division.

SWITCH—Enclosed 16-point switch with 15 resistors of 50 ohms each for high dial.

BINDING POSTS—For external battery, standard cell, keys and galvanometer. Individual binding posts permit using the slidewire in d-c or a-c bridge circuits.

CASE—Gray metal with vinyl dust cover; 7½" x 10¾" x 5", weight approx. 6½ lb.

PRICE—$295.00.

RECOMMENDED ACCESSORIES

4776 Resistance Box	2435-c Galvanometer
7308 Standard Cell	2340-c Galvanometer
3294 DPDT Switch	7597 Battery

OPTIONAL ACCESSORIES

7582 Volt Box
4385 Shunt Box
127272 Angle Bench Bracket

8687 and 8687-2 PRECISION PORTABLE VOLT POTENTIOMETER

VOLT POTENTIOMETER
LEEDS & NORTHRUP CO.
GALVANOMETER

8687 shown

DOUBLE-RANGE MEASUREMENTS (0 to 1.601 and 0 to 0.1601 VOLTS) WITH HIGH ACCURACY AND SENSITIVITY

Two-switches-and-slidewire operation with central readout window

Slidewire overlap eliminates switch operation for small voltage changes

Self-contained with built-in null detector or galvanometer, standard cell, batteries

Convenient standard-cell adjustment for long-term changes in voltage

This double-range instrument is recommended for general-purpose usage where the requirements are high accuracy and sensitivity coupled with high-range capabilities. Null balance is obtained by operating two switches and a one-turn slidewire. The galvanometer has the highest sensitivity of any used in L&N portable potentiometers. Since the final increment of potentiometer voltage is spread over a 220-division slidewire, small fluctuations of measured voltage can be measured rapidly and accurately. In addition, the overlap of the slidewire (total range is 10% greater than the voltage per step of the dial switch) facilitates measuring a voltage fluctuating in the vicinity of the dial switch setting. An L&N Report of Calibration is available (suffix "-B").

SPECIFICATIONS

LIST NUMBERS—8687 (Galvanometer); 8687-2 (Null detector).

RANGES—High Range: 0 to 1.601 volts. Low Range: 0 to 0.1601 volt.

LIMITS OF ERROR—High Range: ±(0.03% of reading + 30 μV). Low Range: ±(0.04% of reading + 3 μV). With L&N Report of Calibration: High Range: ±(0.02% of reading + 20 μV). Low Range: ±(0.02% of reading + 2 μV).

MEASURING DIALS—High Range: "A" Switch, 15 x 0.1 volt; "B" Switch, 9 x 0.01 volt; "C" Slidewire, 0 to 0.011 volt, smallest division 50 μV, adjustable to 10 μV. Low Range: "A" Switch, 15 x 0.01 volt; "B" Switch, 9 x 0.001 volt; "C" Slidewire, 0 to 0.0011 volt, smallest division 5 μV, adjustable to 1 μV.

STANDARD-CELL ADJUSTMENT—Adjustment for any internal standard-cell voltage from 1.0170 to 1.0200 volts.

GALVANOMETER (8687)—Sensitivity: 0.025 μA/mm.

DETECTOR (8687-2)—Sensitivity: 0.5 μV/div.

RHEOSTATS—"Coarse" and "Fine" for adjustment of battery current.

FUNCTION SWITCH—Nine-position for internal connections.

KEYS—Two detector sensitivity keys, one lock-down.

BATTERIES—Self-contained. One 3-volt for measuring circuit. Two 1½-volt for galvanometer lamp (8687); Two 6-volt for detector (8687-2).

CASE—Metal with vinyl finish, handle and removable lid, 14-5/16″ x 11-1/32″ x 7⅜″; weight approx. 21 lb.

PRICE—8687: $560.00; 8687-2: $635.00; "-B" add $140.00.

OPTIONAL ACCESSORIES

099007 Line-operated Lamp Power Supply (8687), Price $33.00.
099055 Line-operated Power Supply (8687-2), Price $40.00.
4385 Shunt Box
7592 Volt Box
9912 Run-up Box

8687-1 PANEL-MOUNTED POTENTIOMETER

POTENTIOMETER
CAT. 8687-1
MEASURE X0.1
OUTPUT X0.1
OUTPUT X1.0
MEASURE X1.0
VOLT BOX
SHUNT BOX
A
B
VOLTS
C
EMF
CALIBRATE
EMF-0
DETECTOR

DOUBLE-RANGE MEASUREMENTS (0 to 1.601 and 0 to 0.1601 VOLTS) WITH HIGH ACCURACY AND SENSITIVITY

Two-switches-and-slidewire operation with central readout window

Slidewire overlap eliminates switch operation for small voltage changes

Convenient standard-cell adjustment for long-term changes in voltage

Designed for mounting in standard 19" panel

The three-dial, double-range 8687-1 Potentiometer is panel-mounted and line-operated. Readout is a series of digits plus a scale interpolation in a central window. This instrument can be used to measure millivolts or thermocouple temperatures. The function switch permits convenient selection of an external shunt box or volt box. An external detector is required.

SPECIFICATIONS

RANGES—High Range: 0 to 1.601 volts. Low Range: 0 to 0.1601 volt.

LIMITS OF ERROR—High Range: ±(0.03% of reading + 30 μV); Low Range: ±(0.04% of reading + 3 μV).

MEASURING DIALS—High Range: "A" Switch: 15 x 0.1 volt; "B" Switch: 9 x 0.01 volt; "C" Slidewire: 0 x 0.011 volt, smallest division 50 μV, adjustable to 10 μV. Low Range: "A" Switch: 15 x 0.01 volt; "B" Switch: 9 x 0.001 volt; "C" Slidewire: 0 x 0.0011 volt, smallest division, 5 μV, adjustable to 1 μV.

FUNCTION SWITCH—Six-position switch for internal connections.

POWER SUPPLY—Line-operated constant-voltage power supply, input 107 to 127 volts a-c, 60/50 Hz.

KEY—One single-pole, single-throw detector key with lock-down position.

CALIBRATION—Internal slidewire rheostat provides adjustment for power-supply output variation of ±0.25%.

INPUT—Ten pairs of terminals on rear terminal board, one pair on front panel, selected by 11-position input switch.

DIMENSIONS—19" panel width x 6-31/32" x 7"; weight approx. 15 lb.

PRICE—$620.00; "-B", add $140.00.

RECOMMENDED ACCESSORIES

Speedomax Recorder and/or
9834-1 Null Detector, or
2437-1-☐ ☐ Null Detector
L&N Deviation Amplifier, or
Automatic Control Units

OPTIONAL ACCESSORIES

4385-1 Shunt Box
7592-1 Volt Box
9912-1 Run-up Box

8691 LONG-SCALE MILLIVOLT POTENTIOMETER

MILLIVOLT POTENTIOMETER
LEEDS & NORTHRUP CO.
PHILADELPHIA MADE IN U.S.A.
CAT. NO. 8677
GALVANOMETER
BATTERY
STANDARDIZE
OUTPUT X 1
OUTPUT X 10
MEASURE X 1
MEASURE X 10
EMF

DOUBLE-RANGE MEASUREMENTS UP TO 1,110 MV WITH LABORATORY ACCURACY AND FINE RESOLUTION

Switch-and-slidewire operation with in-line readout

Slidewire overlap eliminates switch operation for small voltage changes

Self-contained with built-in pointer galvanometer, standard cell, batteries

Laboratory accuracy and the fine resolution possible with a 27.5″ scale make this double-range instrument a good choice for measurements requiring precise readings. The 8691 provides the same slidewire overlap described for the 8687. While the galvanometer system supplied with this potentiometer serves for external resistances up to 2000 ohms (high range), other galvanometers (see table) can be substituted when higher external resistances are to be measured. An L&N Report of Calibration is available (suffix "-B").

SPECIFICATIONS

RANGES—High range: 0 to 1110 mV; low range: 0 to 111 mV.

LIMITS OF ERROR—High range: ±(0.05% of reading + 150 μV); low range: ±(0.05% of reading + 15 μV).

With L&N Report of Calibration: high range: ±(0.02% of reading + 100 μV); low range: ±(0.02% of reading + 10 μV).

MEASURING DIALS—High Range: Millivolt Dial: 10 x 100 mV; Two-turn slidewire: 0 to 110 mV, 27.5″ long, smallest division 200 μV, resolution 50 μV. Low Range: Millivolt Dial: 10 x 10 mV; Two-turn slidewire: 0 to 11 mV, 27.5″ long, smallest division 20 μV, resolution 5 μV.

STANDARD-CELL ADJUSTMENT—Recessed, slotted shaft permits adjusting for standard-cell voltages from 0.0170 to 1.0200 volts.

GALVANOMETER—Sensitivity: 0.6 μA/mm.

RHEOSTAT—Three-turn, battery current adjustment.

FUNCTION SWITCH—Six-position switch to provide internal instrument connections.

KEYS—One single-pole, single-throw galvanometer key with lock-down position.

BATTERY—Self-contained, 1½-volt for measuring circuit.

CASE—Metal with vinyl finish, handle and removable lid; 12-11/32″ x 8-29/32″ x 7⅜″; weight approx. 13 lb.

PRICE—$320.00; "-B" add $175.00.

OPTIONAL ACCESSORIES

4385 Shunt Box
7592 Volt Box
9912 Run-up Box

Galvanometer Systems	Sensitivity μA/mm	Ext. Res. Limits	
		High Range	Low Range
062112*	0.6	0 to 2000 ohms	0 to 200 ohms
062113	0.25	500 to 4000 ohms	10 to 300 ohms
062114	0.1	3000 to 10,000 ohms	200 to 800 ohms

*Supplied with instrument and listed for reference; others are optional and can be field-installed for higher source resistances.

8691-1 PANEL-MOUNTED MILLIVOLT POTENTIOMETER

POTENTIOMETER
CAT 8691-1
EMF
MV
MEASURE X10
OUTPUT X10
MEASURE X1
OUTPUT X1
DETECTOR
CALIBRATE

DOUBLE-RANGE MEASUREMENTS UP TO 1,110 MV WITH LABORATORY ACCURACY AND FINE RESOLUTION

Switch-and-slidewire operation with in-line readout window

Slidewire overlap eliminates switch operation for small voltage changes

Convenient standard-cell adjustment for long-term changes in voltage

Designed for mounting in standard 19″ panel

The 8691-1 is a double-range potentiometer, panel-mounted and line-operated. A single-knob switch plus a high-resolution slidewire provide a millivoltage readout in adjacent centrally-located windows. The sum of the two readings, multiplied by the factor of the function switch, is the actual value in millivolts. An external detector is required.

SPECIFICATIONS

RANGE—High Range: 0 to 1110 mV; Low Range: 0 to 111 mV.

LIMITS OF ERROR—High Range: ±(0.1% of reading + 150 μV); Low Range: ±(0.1% of reading + 15 μV).

MEASURING DIALS—High Range: Millivolt Dial: 10 x 100 mV; Two-turn slidewire: 0 to 110 mV, 27.5″ long, smallest division 200 μV, resolution 50 μV. Low Range: Millivolt Dial: 10 x 10 mV; Two-turn slidewire: 0 to 11 mV, 27.5″ long, smallest division 20 μV, resolution 5 μV.

CALIBRATION—Internal slidewire provides adjustment for power-supply output variation of ±0.25%.

POWER SUPPLY—Line-operated constant-voltage power supply, input 107 to 127 volts a-c, 60/50 Hz.

FUNCTION SWITCH—Four-position switch for internal connections.

KEY—One single-pole, single-throw detector key with lock-down position.

INPUT—Ten pairs of terminals on rear terminal board, one pair on front panel, selected by 11-position input switch.

DIMENSIONS—19″ panel width x 6-31/32″ x 7″; weight approx. 15 lb.

PRICE—$345.00; "-B" add $175.00.

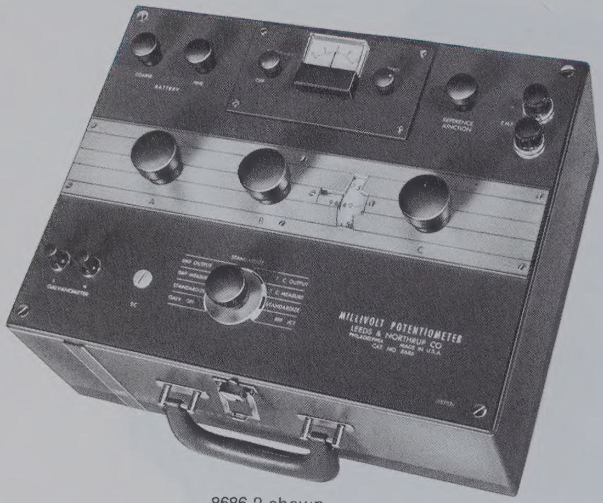
RECOMMENDED ACCESSORIES

Speedomax Recorder, and/or
9834-1 Null Detector, or
2437-1-☐ ☐ Null Detector
L&N Deviation Amplifier, or
Automatic Control Units

OPTIONAL ACCESSORIES

4385-1 Shunt Box
7592-1 Volt Box
9912-1 Run-up Box

8686 and 8686-2 PRECISION MILLIVOLT POTENTIOMETER



8686-2 shown

DOUBLE-RANGE MILLIVOLT MEASUREMENTS WITH HIGHEST L&N ACCURACY IN A PORTABLE

Two-switches-and-slidewire operation with central readout window

Slidewire overlap eliminates switch operation for small voltage changes

Self-contained with built-in null detector or galvanometer, standard cell, batteries

Manual reference-junction compensator for thermocouple measurements

Convenient standard-cell adjustment for long-term changes in voltage

The low range of this double-range instrument extends below zero, permitting continuous measurement, without lead switching, of d-c potentials that fluctuate around zero and of emfs as thermocouples pass through their reference-junction temperature. This range is ideal for field and factory calibration of recorders and meters. The second range facilitates rapid checking of unsaturated cells, such as those used in recorders and other instruments.

Null balance is obtained by operating two switches and a slidewire, and the limit of error is the smallest of any L&N portable. The 220-division slidewire permits the rapid and accurate measurement of small fluctuations of measured voltage, and the slidewire overlap (described for 8687) facilitates measuring a voltage fluctuating in the vicinity of a dial-switch setting.

The 9912 Run-up Box can also be used with this instrument as a millivolt-source option for meter checking or other applications where the load of the device to be checked would otherwise cause errors. For factory installation in deeper lid, order 8686-R or 8686-R2; for field conversion, order 9912 and 124290; box only, order 9912.

An L&N Report of Calibration is available (suffix "-B").

SPECIFICATIONS

LIST NUMBERS—8686 (Galvanometer); 8686-2 (Null detector).

RANGES—(1) −10.100 to +100.100 mV; (2) +1010.000 to +1020.000 mV for standard-cell calibration. Smallest scale division 5 μV; resolution 1 μV.

LIMITS OF ERROR—Without reference-junction compensation: ±(0.03% of reading + 3 μV). With reference-junction compensation: ±(0.03% of reading + 6 μV). With L&N Report of Calibration: without reference-junction compensation: ±(0.02% of reading + 2 μV); with reference-junction compensation: ±(0.02% of reading + 4 μV).

MEASURING DIALS—"A" Switch: 9 x 10 mV plus additional step of 1010 mV and a "minus" position. "B" Switch: 9 x 1 mV. "C" Slidewire: 0 to 1.100 mV on circular scale 12″ long. Smallest division 5 μV. Adjustable to 1 μV.

REFERENCE-JUNCTION COMPENSATOR — Uncalibrated slidewire with range of 0 to 5 mV, adjustable to 2 μV.

STANDARD-CELL ADJUSTMENT—Recessed, slotted shaft permits adjustment for any internal standard-cell voltage from 1.0170 to 1.0200 volts.

GALVANOMETER (8686)—Sensitivity: 0.06 μA/mm.

DETECTOR (8686-2)—Sensitivity: 0.5 μV/div.

RHEOSTATS—"Coarse" and "Fine" for adjustment of battery current.

FUNCTION SWITCH—Nine-position switch to provide internal instrument connections.

KEYS—Two detector sensitivity keys, one a lock-down type.

BATTERIES—Self-contained; one 1½-volt for measuring circuit. Two 1½-volt for galvanometer lamp (8686); two 6-volt for detector (8686-2).

CASE—Metal with vinyl finish, handle and removable lid, 14-5/16″ x 11-1/32″ x 7⅜″; weight approx. 21 lb.

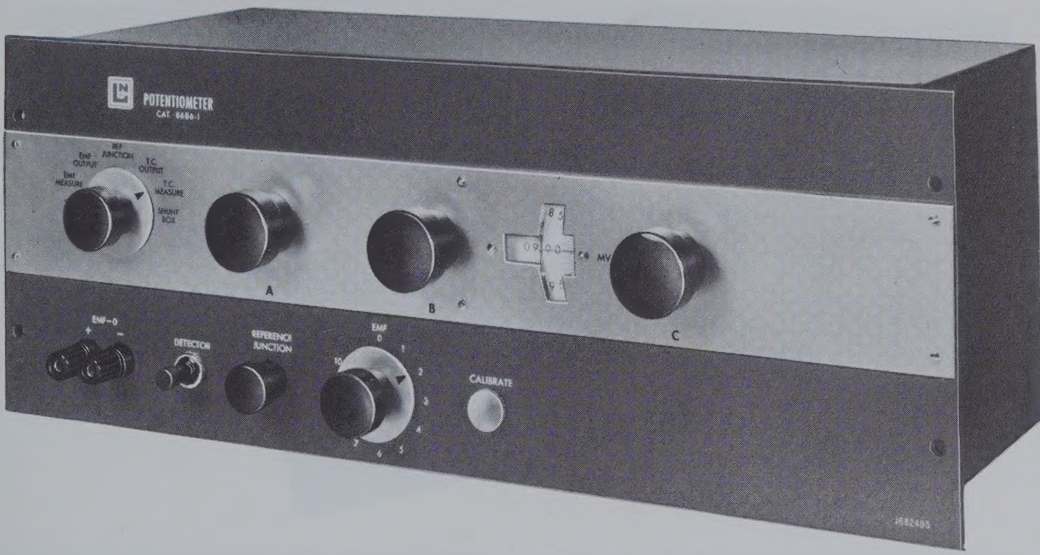
PRICE—8686: $510.00; 8686-R: $580.00; 8686-2: $585.00; 8686-R2: $655.00; "-B" add $120.00.

OPTIONAL ACCESSORIES

4385 Shunt Box
7592 Volt Box
9912 Run-up Box
124290 Kit for Field Conversion to add 9912 to existing instrument. Price $50.00.

099007 Line-operated Lamp Power Supply (8686), Price $33.00.
099055 Line-operated Power Supply (8686-2), Price $40.00.

8686-1 PANEL-MOUNTED MILLIVOLT POTENTIOMETER



DOUBLE-RANGE MILLIVOLT MEASUREMENTS WITH HIGH ACCURACY

Two-switches-and-slidewire operation with central readout window

Slidewire overlap eliminates switch operation for small voltage changes

Manual reference-junction compensator for thermocouple measurements

Convenient standard-cell adjustment for long-term changes in voltage

The 8686-1 is a three-dial double-range potentiometer, panel-mounted and line-operated. Readout in a central window is in the form of a series of digits and a scale interpolation. The basic range extends from −10.1 to +100.1 millivolts and covers the complete millivolt span of all thermocouple outputs, both positive and negative. Therefore, there is no need to reverse inputs. Ideal for thermocouple measurements, this instrument permits convenient reference-junction compensation. The auxiliary range (+1010 to +1020 mV) is supplied for checking standard-cell or Zener-diode supply voltages.

SPECIFICATIONS

RANGE—Basic Range: −10.1 to +100.1 mV; Auxiliary Range: +1010 to +1020 mV. Smallest scale division, 5 μV, resolution 1 μV.

LIMITS OF ERROR—Without reference-junction compensation: ±(0.03% of reading + 3 μV); with reference-junction compensation: ±(0.03% of reading + 6 μV).

MEASURING DIALS—"A" Switch: 9 x 10 mV plus additional step of 1010 mV and a "minus" position; "B" Switch: 9 x 1 mV; "C" Slidewire: 0 to 1.1 mV on circular scale 12″ long.

REFERENCE-JUNCTION COMPENSATOR — Uncalibrated slidewire with range of 0 to 5 mV, adjustable to 2 μV.

FUNCTION SWITCH—7-position for internal connections.

POWER SUPPLY—Line-operated constant-voltage power supply, input 107 to 127 volts a-c, 60/50 Hz.

KEY—One single-pole, single-throw detector key with lock-down position.

CALIBRATION—Internal slidewire provides adjustment for power-supply input variation of ±0.25%.

INPUT—Ten pairs of terminals on rear terminal board, one pair on front panel, selected by 11-position input switch.

DIMENSIONS—19″ panel width x 6-31/32″ x 7″; weight approx. 15 lb.

PRICE—$570.00; "-B" add $120.00.

RECOMMENDED ACCESSORIES

Speedomax Recorder and/or
9834-1 Null Detector, or
2437-1-☐ ☐ Null Detector
L&N Deviation Amplifier, or
Automatic Control Units

OPTIONAL ACCESSORIES

4385-1 Shunt Box
7592-1 Volt Box
9912-1 Run-up Box

8690 LONG-SCALE MILLIVOLT POTENTIOMETER

MILLIVOLT POTENTIOMETER
LEEDS & NORTHRUP CO.
GALVANOMETER
REFERENCE JUNCTION
BATTERY
EMF

MEASUREMENTS FROM −11.0 to +101.0 MV WITHOUT REVERSING INPUT LEADS

Switch-and-slidewire operation with in-line readout window

Measures below 0 mV without input reversal

Self-contained with built-in pointer galvanometer, standard cell, batteries

Manual reference-junction compensator for thermocouple measurements

Standard-cell adjustment for long-term changes in voltage

The range of this instrument from −11.0 to +101.0 mV eliminates the need of reversing input leads when potentials go below zero, and the 27.5″ scale makes it easy to follow continuous changes. This makes it ideal for general measurements and instrument checking. A short-range slidewire provides manual reference-junction compensation for thermocouples.

The 9912 Run-up Box can broaden the application of this instrument in two ways. The Box can supply the current flow needed for checking deflection-type millivoltmeters and similar instruments, and it can be used as a low-resistance mV calibration source for dynamic checks of null-balancing galvanometer-type instruments. This millivolt-source option can be ordered three ways: with the 8690 in a special deeper cover (order 8690-R); as a kit with deep cover and cables for field-installation (order 9912 and 124290); and separately for outboard mounting with copper lugs. An L&N Report of Calibration is available (suffix "-B").

SPECIFICATIONS

RANGE — −11.0 mV to +101.0 mV.

LIMITS OF ERROR—Without reference-junction compensation: ±(0.05% of reading + 15 μV). With reference-junction compensation: ±(0.05% of reading + 30 μV). With L&N Report of Calibration: Without reference-junction compensation: ±(0.02% of reading + 10 μV). With reference-junction compensation: ±(0.02% of reading + 20 μV).

MEASURING DIALS — Millivolt Dial: 9 x 10 mV plus a "minus" position. Slidewire: 0 to 11 mV, two-turn, 27.5″ long; smallest scale division 20 μV, adjustable to 5 μV.

REFERENCE-JUNCTION COMPENSATOR — Uncalibrated multi-turn slidewire, manually operated. Range 0 to 5 mV, adjustable to 5 μV.

STANDARD-CELL ADJUSTMENT—Recessed, slotted shaft permits adjustment for any internal standard-cell voltage from 1.0170 to 1.0200 volts.

GALVANOMETER—Sensitivity: 0.6 μA per scale division.

RHEOSTAT—Three-turn rheostat for adjustment of battery current.

FUNCTION SWITCH—Nine-position switch to provide internal instrument connections.

KEY—One single-pole, single-throw galvanometer key with lock-down position.

BATTERY—Self-contained; one 1½-volt for measuring circuit.

CASE—Metal with vinyl finish, handle and removable lid: 12-11/32″ x 8-29/32″ x 7⅜″; weight approx. 13 lb.

PRICE—8690: $320.00; 8690-R: $390.00; "-B" add $150.00.

OPTIONAL ACCESSORIES

9912 Run-up Box
124289 Kit for Field Conversion to add 9912 to existing instrument. Price $46.75.

8690-1 PANEL-MOUNTED MILLIVOLT POTENTIOMETER

POTENTIOMETER
CAT. 8690-1
EMF
T.C. MEASURE
T.C. OUTPUT
REFERENCE JUNCTION
EMF MEASURE
EMF OUTPUT
REF JUNCTION
CALIBRATE
MV
EMF=0
DETECTOR
CALIBRATE

DOUBLE-RANGE MEASUREMENTS
(−11.0 to +101.0 MV and 989 to 1101 MV)

Switch-and-slidewire operation with in-line readout window

Measures below 0 mV without input reversal

Manual reference-junction compensator for thermocouple measurements

Built-in line-operated Zener-diode power supply

Operation over a wide ambient-temperature range

Multiple switch selection of inputs for comparison of thermocouples

Convenient standard-cell adjustment for long-term changes in voltage

The 8690-1 is a double-range potentiometer, panel-mounted and line-operated. A single-knob switch plus a high-resolution slidewire provide a millivoltage readout in adjacent centrally-located windows. The basic range (−11 to +101 mV) covers the complete millivolt span of all thermocouple outputs, both positive and negative.

Reference-junction compensation is made by merely adjusting a single knob on the front panel. The auxiliary range (989 to 1101 mV) is used for standard-cell checking or for calibration of Zener-diode reference supplies. An external detector is required.

SPECIFICATIONS

RANGE—Basic Range: −11 to +101 mV; Auxiliary Range: 989 to 1101 mV.

LIMITS OF ERROR—Without reference-junction compensation: ±(0.1% of reading + 15 μV); With reference-junction compensation: ±(0.1% of reading + 30 μV).

MEASURING DIALS — Millivolt Dial: 9 x 10 mV plus a "minus" position; Slidewire: 0 to 11 mV, two-turn, 27.5″ long, smallest scale division 20 μV, with resolution of 5 μV.

REFERENCE-JUNCTION COMPENSATOR — Uncalibrated multi-turn slidewire, manually operated. Range 0 to 5 mV, adjustable to 2 μV.

CALIBRATION—Internal slidewire provides adjustment for power supply output variation of ±0.25%.

POWER SUPPLY—Line-operated constant-voltage power supply, input 107 to 127 volts a-c, 60/50 Hz.

FUNCTION SWITCH—Six-position switch for internal connections.

KEY—One single-pole, single-throw detector key with lock-down position.

INPUT—Ten pairs of terminals on rear terminal board, one pair on front panel, selected by 11-position input switch.

DIMENSIONS—19″ panel width x 6-31/32″ x 7″; weight approx. 15 lb.

PRICE—$345.00; "-B" add $150.00.

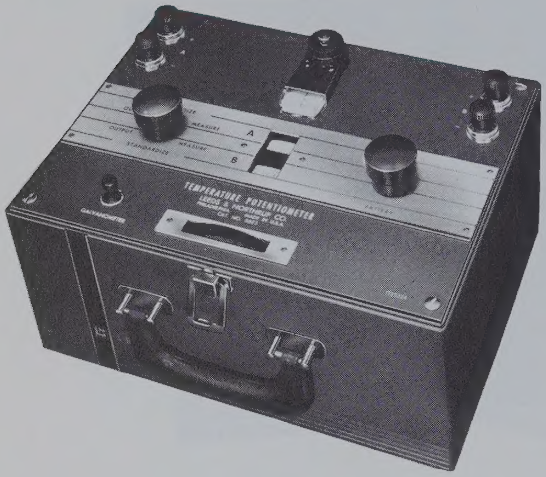
RECOMMENDED ACCESSORIES

Speedomax Recorder and/or
9834-1 Null Detector, or
2437-1-☐ ☐ Null Detector
L&N Deviation Amplifier, or
Automatic Control Units.

OPTIONAL ACCESSORIES

4385-1 Shunt Box
7592-1 Volt Box
9912-1 Run-up Box

8692-☐ SINGLE-RANGE LONG-SCALE POTENTIOMETER
8693-☐ DOUBLE-RANGE LONG-SCALE POTENTIOMETER



SINGLE- OR DOUBLE-RANGE INSTRUMENTS WITH A SELECTION OF THERMOCOUPLE AND MILLIVOLT SCALES

Switch-and-slidewire operation with central readout window

Direct-reading in degrees F or C

Self-contained with built-in pointer galvanometer, standard cell, batteries

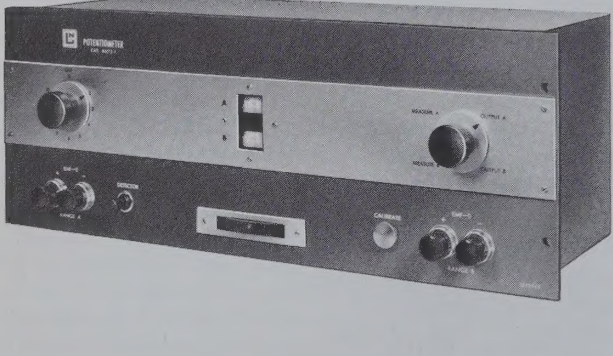
Automatic reference-junction compensation

Simplified range change—no soldering required

Both of these long-scale potentiometers combine convenience and accuracy to a high degree. The 27.5″ scales provide highly accurate readout and permit close interpolations on all scales. The double-range 8693 can have any desired pairing of temperature and millivolt, standard and special scales.

In addition to the standard ranges shown in Table 1, many special ranges can be supplied on order. These specials are hand-drawn and are provided at extra cost. Ranges can be readily changed by substituting

8692-1-☐ SINGLE-RANGE PANEL-MOUNTED POTENTIOMETER
8693-1-☐ DOUBLE-RANGE PANEL-MOUNTED POTENTIOMETER



SINGLE- OR DOUBLE-RANGE INSTRUMENTS WITH A SELECTION OF THERMOCOUPLE AND MILLIVOLT SCALES

Switch-and-slidewire operation with central readout window

Automatic reference-junction compensator for thermocouple measurements

Built-in line-operated Zener-diode power supply

Multiple switch selection of inputs for comparison of thermocouples

The 8692-1 is a single-range, direct-reading potentiometer with built-in, line-operated constant-voltage supply. Individual ranges are selected from 32 different standard thermocouple ranges and four millivolt ranges and are easily interchanged (see Table 1). Special ranges are available on request.

Direct readout, in degrees, is at a centrally-located window equipped with a clear, distinct hairline for operator ease and accuracy.

The 8693-1 is a double-range, direct-reading potentiometer identical to the 8692-1, but having two direct-reading slidewire scales appearing in adjacent windows the desired scale, its range resistor panel and, in some cases, a binding post (see Table 2). A reference-junction coil is built into the range-resistor panel to automatically compensate for the type of thermocouple being used.

SPECIFICATIONS

RANGES—8692: Any standard range as specified.
8693: Any two standard ranges as specified.
Add range suffix number(s) to List Number.

LIMITS OF ERROR—±0.2% of span.

MEASURING DIALS—8692: One scale, 27.5″ long.
8693: Two scales, each 27.5″ long.
Scales mounted on two-turn slidewire (see range listing for smallest scale division).

REFERENCE-JUNCTION COMPENSATOR—Automatic on all temperature ranges.

FUNCTION SWITCHES—8692: Three-position switch.
8693: Six-position switch.

GALVANOMETER—Sensitivity, 1.0 μA per scale division.

BATTERY RHEOSTAT—Three-turn rheostat for adjustment of battery current.

KEY—One single-pole, single-throw galvanometer key with lock-down position.

BATTERY—Self-contained; one 1½-volt for measuring circuit.

CASE—Metal with vinyl finish, handle and removable lid; 12-11/32″ x 8-29/32″ x 7⅜″; weight approx. 13 lb.

PRICE—8692-☐☐☐: $295.00; 8693-☐☐☐-☐☐☐: $355.00.

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corresponding to its two ranges. Any combination of ranges can be selected from Table 1. Reference-junction compensation is automatic for both ranges. An external detector is required.

SPECIFICATIONS

RANGES—8692-1: Any standard range as specified.
8693-1: Any two standard ranges as specified.
Add range suffix number(s) to List Number.

LIMITS OF ERROR—±0.2% of range span in millivolts.

MEASURING DIALS—8692-1: One scale, 27.5″ long.
8693-1: Two scales, each 27.5″ long.
Scales mounted on two-turn slidewire (see range table for smallest scale division).

REFERENCE-JUNCTION COMPENSATOR—Automatic on all temperature ranges.

CALIBRATION—Internal slidewire provides adjustment for power-supply output variation of ±2.5%.

POWER SUPPLY—Line-operated constant-voltage power supply, input 107 to 127 volts a-c, 60/50 Hz.

FUNCTION SWITCHES—8692-1: Two-position switch.
8693-1: Four position switch.

KEY—One single-pole, single-throw detector key with lock-down position.

INPUT—Ten pairs of terminals on rear board, one pair on front panel (one pair for each range on 8693-1), selected by 11-position input switch.

DIMENSIONS—19″ panel width x 6-31/32″ x 7″; weight approx. 15 lb.

PRICE—8692-1-☐☐☐: $320.00; 8693-1-☐☐☐-☐☐☐: $380.00.

TABLE 1—STANDARD RANGES

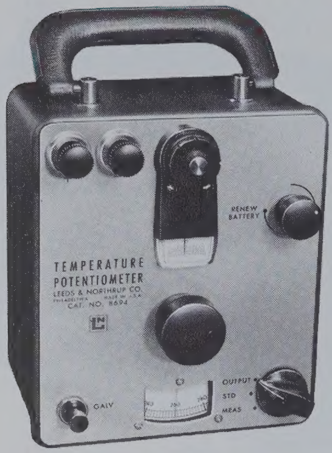
Type Of Thermocouple	Range	Smallest Scale Division	Suffix No.
Iron & Constantan	0 to 300 F	0.5 F	048
	−100 to +500 F	1.0 F	009
	0 to 1000 F	2.0 F	003
	400 to 1200 F	2.0 F	172
	0 to 1600 F	5.0 F	142
	0 to 2000 F	5.0 F	049
	900 to 2000 F	2.0 F	164
	−55 to 105 C	0.5 C	513
	0 to 200 C	0.5 C	007
	−100 to +400 C	1.0 C	166
	0 to 500 C	1.0 C	022
	0 to 800 C	2.0 C	057
	0 to 1100 C	2.0 C	165
Chromel & Alumel	0 to 700 F	2.0 F	200
	0 to 1200 F	2.0 F	024
	0 to 2000 F	5.0 F	001
	0 to 2500 F	5.0 F	143
	1000 to 2500 F	5.0 F	046
	0 to 600 C	1.0 C	062
	0 to 1200 C	2.0 C	047
	500 to 1200 C	2.0 C	167
Plat., 10% Rhodium And Platinum	0 to 2500 F	5.0 F	033
	0 to 3200 F	5.0 F	144
	2000 to 3200 F	2.0 F	052
	0 to 1600 C	5.0 C	067
Plat., 13% Rhodium And Platinum	0 to 3200 F	5.0 F	145
Copper & Constantan	−340 to +230 F	−340 to −100 F 2.0 F −100 to +230 F 1.0 F	168
	−100 to +400 F	1.0 F	032
	0 to 650 F	2.0 F	201
	−200 to +150 C	−200 to −150 C 2.0 C −150 to +50 C 1.0 C 50 to 150 C 0.5 C	170
	−100 to +300 C	1.0 C	146
	0 to 400 C	1.0 C	169
Millivolts	−5 to 0 to +5	0.02	084
	0 to 10	0.02	044
	0 to 25	0.05	127
	0 to 50	0.10	045

TABLE 2—RANGE-CHANGE PARTS

Complete the Part Numbers by entering digits of desired scale in the squares.

Scale and slidewire	189☐☐☐	$ 5.50
Range-resistor Panel incl. Reference-junction Resistor	605☐☐☐	$39.00
Binding Post Stud (if required)	061467 Copper Binding Post Stud—Used for positive post for CA and CC thermocouples, positive (+) and negative (−) post for Platinum, 10% Rhodium—Platinum and Platinum, 13% Rhodium—Platinum thermocouples.	$ 0.80
	061468 Constantan Binding Post Stud—Used for negative(−) post for CA, CC and IC thermocouples.	$11.75
	061469 Iron Binding Post Stud—Used for positive (+) post for IC thermocouples.	$ 2.00

8694-☐ SINGLE-RANGE COMPACT POTENTIOMETER
8695-☐ DOUBLE-RANGE COMPACT POTENTIOMETER


RENEW BATTERY
TEMPERATURE POTENTIOMETER
LEEDS & NORTHRUP CO.
CAT. NO. 8694
GALV
OUTPUT
STD
MEAS

SINGLE- OR DOUBLE-RANGE INSTRUMENTS
WITH A SELECTION OF
THERMOCOUPLE SCALES

Direct-reading scale in degrees F

Self-contained with built-in pointer galvanometer, standard cell, batteries

Automatic reference-junction compensation on all temperature ranges

These lightweight, compact and low-cost potentiometers are ideal for many routine temperature checks in almost any locale. The double-range 8695 is especially useful when two types of thermocouples are used—each can be automatically compensated for reference-junction variations. Sixteen standard scales are available, covering the five most-used thermocouple types (see Table 3). Non-standard scales can usually be drawn to order at extra charge. Temperature compensation is automatic on all ranges.

Range-change kits include a slidewire with the proper scale and resistors mounted on it. On the double-range 8695, both ranges are changed as a unit. If the changed range requires a different thermocouple type, a matching reference-junction resistor will be required and, if needed, a different binding post (see Table 4).

SPECIFICATIONS

RANGES—8694: Any standard range as specified.
8695: Any two standard ranges as specified.
Add range suffix number(s) to List Number.

LIMIT OF ERROR—±0.3% of range.

MEASURING DIALS—8694: One scale 13½″ long.
8695: Two scales, 11¼″ and 13½″ long.
Scales mounted on single-turn slidewire (see range lists for smallest scale divisions).

8696 COMPACT MILLIVOLT POTENTIOMETER

REFERENCE JUNCTION
RENEW BATTERY
MILLIVOLT POTENTIOMETER
LEEDS & NORTHRUP CO.
CAT. NO. 8696
GALV
OUTPUT
REF JCT
A
MEAS
STD
B
MEAS
OUTPUT

DOUBLE-RANGES OF 0 TO 22
AND 20 TO 64 MILLIVOLTS
IN A COMPACT, ECONOMICAL UNIT

Direct-reading scale

Self-contained with built-in pointer galvanometer, standard cell, batteries

Manual reference-junction compensator for thermocouple measurements.

REFERENCE-JUNCTION COMPENSATOR—Automatic on all temperature ranges.

FUNCTION SWITCH—8694: Three-position switch. 8695: Six-position switch.

GALVANOMETER—Sensitivity: 0.6 μA per scale division.

BATTERY RHEOSTAT—Single-turn rheostat with 45° vernier action, for adjustment of battery current.

KEY—One single-pole, single-throw galvanometer key with lock-down position.

TABLE 3—STANDARD RANGES

Type Of Thermocouple	Range	Smallest Scale Division	Suffix Number		
			For 8694	For 8695	
				Inside Scale ("A")	Outside Scale ("B")
Iron & Constantan	−100 to +400 F	2 F	828	428	828
	0 to 1200 F	5 F	829	429	829
	0 to 2000 F	10 F	830	430	830
	300 to 1200 F	5 F	831	431	831
	1000 to 2000 F	5 F	832	432	832
Chromel & Alumel	0 to 1200 F	5 F	833	433	833
	0 to 2500 F	10 F	834	434	834
	1100 to 2500 F	5 F up to 2000 F, 10 F above.	835	435	835
Plat., 10% Rhodium And Platinum	0 to 3200 F	20 F up to 1200 F, 10 F above.	836	436	836
	1500 to 3200 F	10 F	837	437	837
Plat., 13% Rhodium And Platinum	0 to 3200 F	20 F up to 1200 F, 10 F above.	838	438	838
	1500 to 3200 F	10 F	839	439	839
Copper & Constantan	−200 to +250 F	2 F	840	440	840
	0 to 750 F	5 F	841	441	841
	−100 to +400 F	2 F	842	442	842
	−320 to +100 F	2 F up to 0 F, 1 F above	858	458	858

BATTERY—Self-contained: two 1½-volt (size D) cells for the measuring circuit.

CASE—Metal with vinyl finish, plastic handle; 7″ x 6″ x 5″; weight approx. 4½ lb.

PRICE—8694-☐☐☐: $210.00. 8695-☐☐☐-☐☐☐: $250.00.

OPTIONAL ACCESSORY

039733 Leather Carrying Case. Price $37.25.

TABLE 4—RANGE-CHANGE PARTS

Complete the Part Numbers by entering digits of desired scale in the squares.

Scale and slidewire	124800—☐☐☐ for 8694 124400—☐☐☐ ☐☐☐ for 8695	$56.00 91.00
Reference-junction Resistor	Iron Constantan . . . . .010788 Chromel-Alumel . . . . .010789 Plat., 10% Rhod.—Plat. . . . . .010790 Plat., 13% Rhod.—Plat. . . . . .010790 Copper Constantan 010791	17.00 17.50 19.00 19.00 15.00
Binding Post Stud (if required)	061467 Copper Binding Post Stud—Used for positive post for CA and CC thermocouples, positive (+) and negative (−) post for Platinum, 10% Rhodium—Platinum and Platinum, 13% Rhodium—Platinum thermocouples.	0.80
	061468 Constantan Binding Post Stud—Used for negative(−) post for CA, CC and IC thermocouples.	11.75
	061469 Iron Binding Post Stud—Used for positive (+) post for IC thermocouples.	2.00

This double-range 8696 potentiometer is ideal where light weight, compactness and economy are important considerations. The high-sensitivity galvanometer can detect slight potential-difference changes and the scale ranges can provide high readability of interpolated readings. Emfs of thermocouples can be read and converted to temperatures. For this application a manually-operated slidewire provides reference-junction compensation. Millivolt readings provide versatility for use with other transducers and for checking recorders. The metal case and vinyl finish of this instrument are designed to withstand hard usage.

SPECIFICATIONS

RANGE—Two: 0 to 22 mV and 20 to 64 mV.

LIMITS OF ERROR—±(0.3% of range) without reference-junction compensation; ±(0.3% of range + 45 μV) with reference-junction compensation.

MEASURING DIALS—0 to 22 and 20 to 64 mV; single-turn; Low-range, 11¼″ scale, smallest scale division 100 μV, resolution 20 μV; High-range, 13½″ scale, smallest scale division 200 μV, resolution 40 μV.

REFERENCE-JUNCTION COMPENSATOR — Uncalibrated single-turn slidewire with 45° vernier action, manually operated. Range: 0 to 5 mV, adjustable to 5 μV.

STANDARD-CELL ADJUSTMENT—Recessed, slotted shaft permits adjusting for standard-cell voltages from 1.0170 to 1.0200 volts.

GALVANOMETER—Sensitivity, 0.6 μA/mm.

RHEOSTAT—Single-turn with 45° vernier action for battery.

FUNCTION SWITCH—Six-position switch to provide internal instrument connections.

KEYS—One single-pole, single-throw galvanometer key with lock-down position.

BATTERIES—Self-contained; two 1½-volt (size D) cells for the measuring circuit.

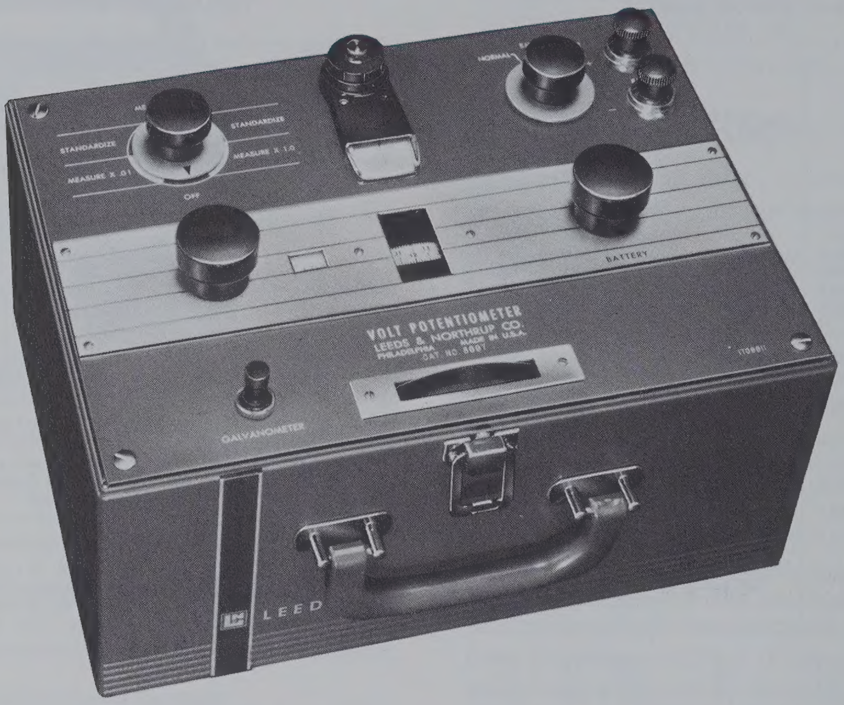
CASE—Metal with vinyl finish, plastic handle: 7″ x 6″ x 5″; weight approx. 4½ lb.

PRICE—$250.00.

OPTIONAL ACCESSORY

039733 Leather Carrying Case. Price $37.25.

8697 LONG-SCALE PORTABLE VOLT POTENTIOMETER



MEASUREMENTS OF ZENER AND CORROSION POTENTIALS TO 11.10 VOLTS

Switch-and-slidewire operation with in-line readout window

Self-contained with built-in pointer galvanometer, standard cell, batteries

Standard-cell adjustment for long-term changes in voltage

This high-range instrument fills the need for a unit to measure accurately the corrosion potentials between buried metals (pipelines, cables, tower supports) and the earth, as a guide to applying cathodic protection. It is also used to measure control-point voltages of Zener diodes. Null balance is obtained by operating a switch and slidewire, and a function switch provides three ranges. This instrument also provides the slidewire overlap described for the 8687.

SPECIFICATIONS

RANGE—X1 range: 0 to 11.10 V; X.1 range: 0 to 1.110 V; X.01 range: 0 to 0.111 V.

LIMITS OF ERROR—±(0.05% of reading + one scale division).

MEASURING DIALS—Switch, 10 x 1 volt; slidewire, 0 to 1.100 V, 27.5″ long. X1 range: smallest division 0.002 V, adjustable to 500 μV; X.1 range: smallest division 200 μV, adjustable to 50 μV; X.01 range: smallest division 20 μV, adjustable to 5 μV.

STANDARD-CELL ADJUSTMENT—Recessed, slotted shaft permits adjusting for standard-cell voltages from 1.0170 to 1.0200 volts.

GALVANOMETER—Sensitivity, 0.25 μA/mm.

RHEOSTAT—Ten-turn, battery current adjustment.

FUNCTION SWITCH—Six-position switch to provide internal instrument connections.

KEYS—One single-pole, single-throw galvanometer key with lock-down position.

BATTERIES—Self-contained; ten 1½-volt cells.

CASE—Metal with vinyl finish, handle and removable lid; 12-11/32″ x 8-29/32″ x 7⅜″; weight approx. 13 lb.

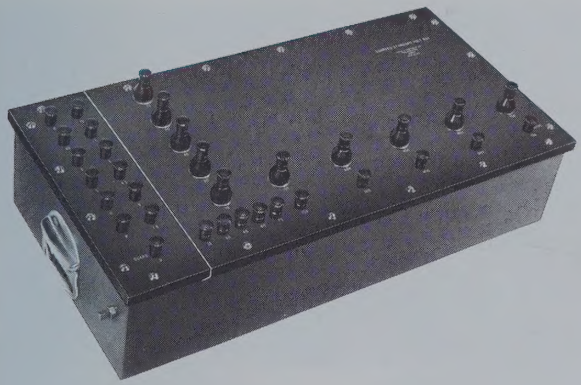
PRICE—$765.00.

7594 GUARDED STANDARD VOLT BOX

TWENTY RANGES TO 750 VOLTS . . .
ACCURACY TO A FEW PPM

Usable in any plane

Accurate self-calibration



The 7594 is a high-accuracy guarded d-c volt box designed for use as a comparison standard in certifying other volt boxes. It duplicates the design described by Silsbee and Gross (NBS Research Paper RP1419) and meets NBS requirements (RP67C1-114) for a standard volt box. Effects from self-heating and humidity are minimal. Its aluminum case is provided with pipe taps for purging with dry air if extremely high humidity conditions are encountered. Matched resistors are used—bifilar wound from the same spool. All binding posts and the resistor sub-panel are completely guarded. Versatile and convenient to use, the volt box can be positioned in any plane without affecting accuracy. An L&N Report of Calibration is available (suffix "-B").

SPECIFICATIONS

RANGE—0 to 750 volts, with taps at 0.15, 0.30, 0.45, 0.60, 0.75, 1.5, 3.0, 4.5, 6.0, 7.5, 15, 30, 45, 60, 75, 150, 300, 450, 600, and 750 volts.

LIMIT OF ERROR OF RATIOS— ±0.005% of nominal, including effects of self-heating and drift for one year.

L&N REPORT OF CALIBRATION — States ratio values to an accuracy of 0.001%.

MEASURING-CIRCUIT RESISTANCE—1333-1/3 ohms per volt. Guarded for voltages of 15 volts or higher.

GUARD-CIRCUIT RESISTANCE—1333-1/3 ohms per volt. No leakage path subject to more than 75 volts.

CASE—27½" x 13⅝" x 7" (including binding posts); weight approximately 54 lb.

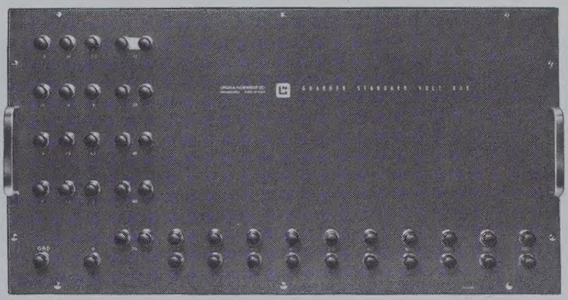
PRICE—P.O.R.

7594-2 GUARDED STANDARD VOLT BOX

TWENTY-FIVE RANGES TO 1500 VOLTS . . .
ACCURACY TO A FEW PPM

Usable in any plane

Designed for rapid self-calibration



This high-accuracy, guarded d-c volt box is designed as a comparison standard to certify other volt boxes. A tap at 1.5 volts permits the accurate measurement of higher voltages by a precision potentiometer. It may also be used as a working volt box to check digital voltmeters. Effect of self-heating of the resistors is minimized by making all resistors from the same spool of wire; current leakage across the insulation is reduced to a negligible amount by providing a guard circuit in parallel with the measuring circuit. The instrument can be positioned in any plane without affecting accuracy. An L&N Report of Calibration is available (suffix "-B").

SPECIFICATIONS

RANGE—0 to 1500 volts with taps at: 0.15, 0.30, 0.45, 0.60, 0.75, 1.5, 3.0, 4.5, 6.0, 7.5, 15, 30, 45, 60, 75, 150, 300, 450, 600, 750, 900, 1050, 1200, 1350, and 1500 volts.

LIMITS OF ERROR—All ratios adjusted to within 0.001% (±10 ppm) of nominal (initial); guaranteed maximum drift (first year) ±10 ppm. Effect of self-heating on ratios: (up to 750 V) ±1 ppm max.; (up to 1500 V) ±5 ppm max.

L&N REPORT OF CALIBRATION—States ratio values to confidence level of 10 ppm.

MEASURING-CIRCUIT RESISTANCE—1333-1/3 ohms per volt, 2 megohms total.

GUARD-CIRCUIT RESISTANCE—1333-1/3 ohms per volt, 2 megohms total.

INPUT IMPEDANCE—667 ohms per volt at max. tap voltage.

CASE—30" x 15⅞" x 8¾" (including binding posts); weight approx. 40 lb.; no thermostated oil bath.

PRICE—$3700.00; "-B", add $450.00.

NOTE: A special rack-mounted version is available; information on request.

7582, 7592, 7593 VOLT BOXES FOR BENCH USE

High-quality type 31 enclosed silver-alloy switches

Metal case and top plate provide electrostatic shielding

Low current drain on the unknown voltage

Open position on selector switch . . . line connections need not be removed

These L&N volt boxes are specifically designed for use with Type K Potentiometers in the d-c calibration of voltmeters and wattmeters, and in other applications in which the voltages exceed the maximum range of the potentiometers. Design features include: a rotary range-selector switch and direct-reading of range setting; a resistance of 750 ohms per volt to provide a large total resistance and therefore a proportionally smaller current drain on the unknown voltage; acrylonitrile-styrene copolymer binding posts mounted on a metal top plate; high-quality L&N selector switches for low, stable contact resistance and low thermal emfs; and woven manganin-wire resistors for excellent stability and high accuracy. An L&N Report of Calibration is available for each of these volt boxes (suffix "-B").

SPECIFICATIONS

RANGES—7582: 15, 150 and 300 volts.
7592: 3, 7.5, 15, 30, 75, 150, 300 and 750 volts.
7593: 3, 7.5, 15, 30, 75, 150, 300, 750 and 1500 volts.

OHMS PER VOLT—750.

OUTPUT VOLTAGE—150 mV.

LIMIT OF ERROR—±0.02%.

CASE—Metal, with vinyl cover; 6⅞″; x 6½″ x 5½″; weight approx. 5 lb.

PRICE—7582: $135.00; "-B" $120.00
7592: $237.00; "-B" $175.00
7593: $350.00; "-B" $190.00.

7592-1 PANEL-MOUNTED VOLT BOX

High-quality type 31 enclosed silver-alloy switches

Metal case and top plate provide electrostatic shielding

Low current drain on the unknown voltage

Open position on selector switch . . . line connections need not be removed

This panel-mounted volt box is used for extending the range of a measuring potentiometer up to 750 volts, thereby permitting measurements which exceed the potentiometer's basic ranges. Precision woven manganin resistors and a high-quality Type 31 selector switch combine to provide high accuracy with excellent mechanical and electrical stability.

SPECIFICATIONS

RANGE—2, 5, 10, 20, 50, 100, 200 and 500 volts.*

OHMS PER VOLT—1125.

OUTPUT VOLTAGE—100 mV at rated input.

LIMIT OF ERROR—±0.02%.

DIMENSIONS—Mounted in rack-mounting frame (with blank panels or other accessory equipment) 19″ wide x 5-7/32″ high; weight approx. 5 lb.

PRICE—$237.00.

**Can be safely operated at 150% of rating, of each step, at slightly decreased accuracy.*

RECOMMENDED ACCESSORIES

The following accessories are available for mounting the 7592-1 Volt Box, the 4385-1 Shunt Box and/or the 9912-1 Run-up Box in a 19″ panel:

124592 Frame: $33.00.

269178 Blank Plate: $2.00 each.
One-third standard 19″ width. Two required if no other accessories are mounted.

4385 SHUNT BOX FOR BENCH USE

High-quality type 31 enclosed silver-alloy switches

Metal case and top plate provide electrostatic shielding

Low power dissipation reduces errors due to self-heating

GRD
LINE
GRD
POTENTIOMETER
SHUNT BOX
CAT 4385
LEEDS & NORTHRUP CO.
MULT BY
MAX AMP

The 4385 Shunt Box is designed for use with L&N Type K Potentiometers in the precise measurement of d-c currents and in the calibration of d-c ammeters and wattmeters. Design features include: a range-selector switch providing digital presentation of maximum current and multiplying factors; low 2.25-watt power dissipation, eliminating the need for a ventilated case; acrylonitrile-styrene copolymer binding posts mounted on a metal top plate; and high-quality L&N selector switches and manganin resistors. An L&N Report of Calibration is available (suffix "-B").

SPECIFICATIONS

RANGE—0.075, 0.15, 0.3, 0.75, 1.5, 3, 7.5 and 15 amperes.

TOTAL RESISTANCE—2.0 ohms.

OUTPUT VOLTAGE—150 mV.

LIMIT OF ERROR—±0.02% at 25 C.

CASE—Metal, with vinyl cover; 6⅞" x 6½" x 5½"; weight approx. 4 lb.

PRICE—$170.00; "-B" $325.00.

4385-1 PANEL-MOUNTED SHUNT BOX

High-quality type 31 enclosed silver-alloy switches

Metal case and top plate provide electrostatic shielding

Low power dissipation reduces errors due to self-heating

The 4385-1 is a panel-mounted potentiometer accessory for precise d-c current measurements and meter calibration. The box provides eight switch-selected shunts permitting precision potentiometer measurements of up to 15 amperes. Features include high-quality Type 31 selector switches, electrostatic shielding and acrylonitrile-styrene copolymer insulated binding posts.

SPECIFICATIONS

RANGE—0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10 amperes.*

TOTAL RESISTANCE—2.0 ohms.

OUTPUT VOLTAGE—100 mV at rated input.

LIMIT OF ERROR—±0.02% at 25 C.

DIMENSIONS—Mounted in rack-mounting frame (with blank panels or other accessory equipment) 19" wide x 5-7/32" high; weight approx. 5 lb.

PRICE—$170.00.

Can be safely operated at 150% of each step, at slightly decreased accuracy.

RECOMMENDED ACCESSORIES

The following accessories are available for mounting the 7592-1 Volt Box, the 4385-1 Shunt Box and/or the 9912-1 Run-up Box in a 19" panel:

124592 Frame: $33.00.

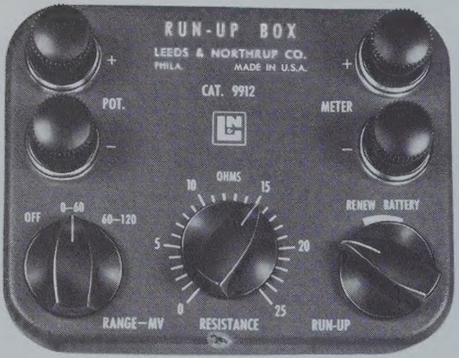
269178 Blank Plate: $2.00 each.
One-third standard 19" width. Two required if no other accessories are mounted.

9912 RUN-UP BOX FOR BENCH USE

Convenient range selection . . . 0 to 60 and 60 to 120 mV

Adjustable series resistance

Coarse and fine millivoltage output adjustments with run-up knob



The 9912 Run-up Box is a battery-operated, low-resistance source of adjustable d-c millivoltage for checking and calibrating instruments which require current flow for their operation, such as deflection-type millivolt indicators. It is also used for dynamic checking of low-range Micromax recorders or similar galvanometer-type null-balance instruments which require low-resistance mV calibration sources.

The Run-up Box can be supplied as a separate item, with two gold-plated straps for connection to the potentiometer binding posts, or can be mounted in a modified, deeper lid provided with new 8686 or 8690 Potentiometers. Conversion kits including the modified lid can be supplied for field-mounting on potentiometers already in use. (Order conversion kit plus run-up box separately.)

SPECIFICATIONS

LIST NUMBERS—9912 Run-up Box; 124290 Conversion Kit for 8686; 124289 Conversion Kit for 8690.

RANGES—0 to 60 and 60 to 120 mV, adjustable to better than ±0.02 mV.

OUTPUT SERIES RESISTANCE—Adjustable from 0 to 25 ohms, to within 0.5 ohm.

BATTERY—Std 986 Battery, 1½ volts; current drain, approximately 4 mA; operating life, 500 hrs, minimum shelf life, approximately 1 year.

TERMINALS—Two pair.

CASE—5⅛″ x 3⅞″ x 2⅝″; weight approx. 1½ lb.

PRICE—9912: $70.00; 124290 (conversion kit for 8686): $50.00; 124289 (conversion kit for 8690): $46.75.

9912-1 PANEL-MOUNTED RUN-UP BOX

Convenient range selection . . . 0 to 60 and 60 to 120 mV

Adjustable series resistance

Coarse and fine millivoltage output adjustments with run-up knob

Convenient meter connections on front and rear panels

The panel-mounted run-up box is a battery-operated, adjustable low-impedance source of current supplied through a calibrated, variable resistance to simulate external circuit resistance. It is used in conjunction with a potentiometer to check and calibrate millivoltmeters that require current flow for their indication.

SPECIFICATIONS

RANGE—0 to 60, and 60 to 120 mV, adjustable to better than ±0.02 mV.

OUTPUT SERIES RESISTANCE—Adjustable from 0 to 25 ohms, to within 0.5 ohm.

BATTERY—Std 986 Battery, 1½ volts; current drain, approximately 4 mA; operating life 500 hours minimum; shelf life, approximately 1 year.

TERMINALS—One pair on front panel; two pairs rear mounted.

DIMENSIONS—Mounted in rack-mounting frame (with blank panels or other accessory equipment), 19″ wide x 5-7/32″ high; weight approx. 1½ lb.

PRICE—$70.00.

RECOMMENDED ACCESSORIES

The following accessories are available for mounting the 7592-1 Volt Box, the 4385-1 Shunt Box and/or the 9912-1 Run-up Box in a 19″ panel:

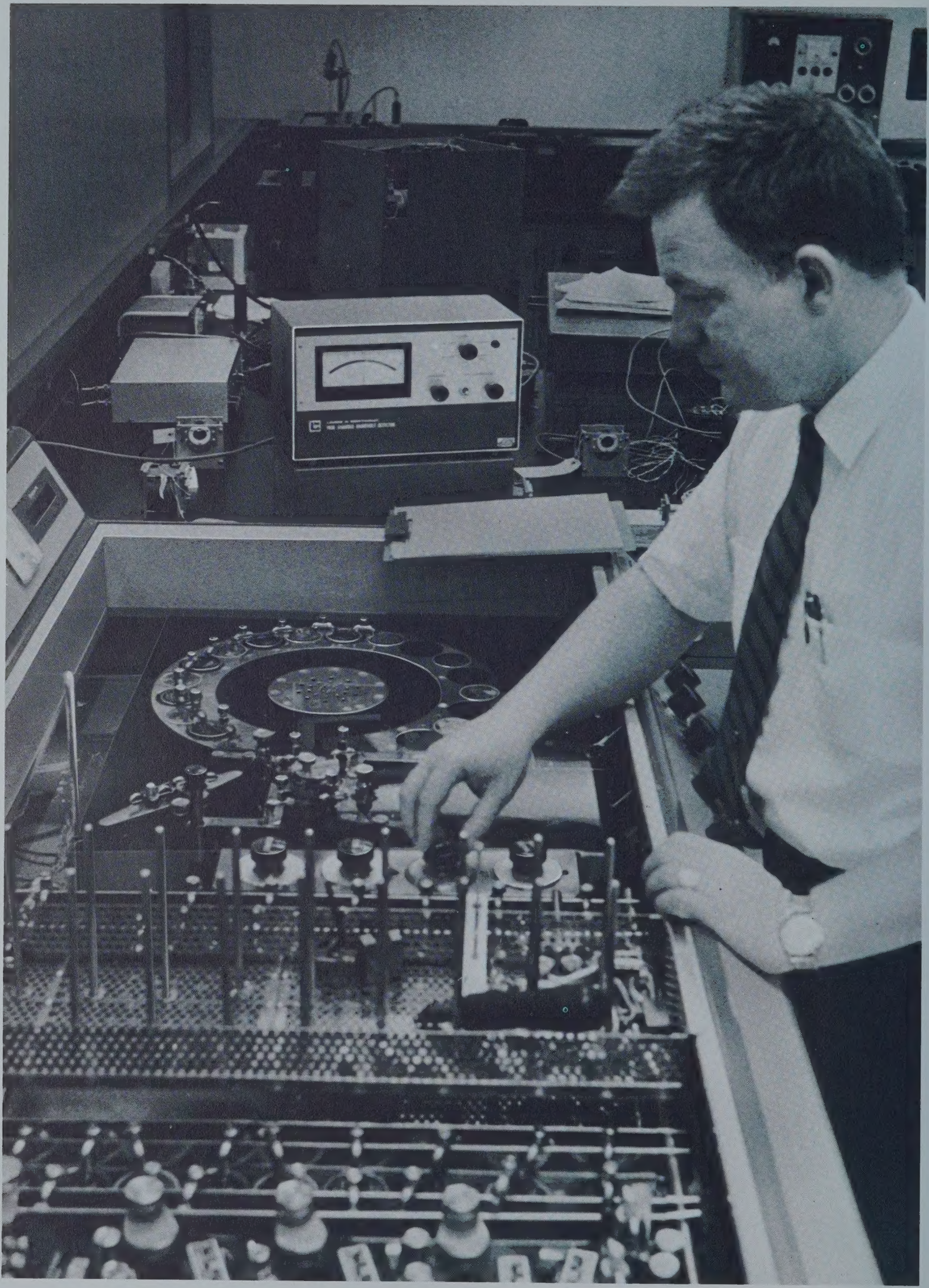
124592 Frame: $33.00.

269178 Blank Plate: $2.00 each.
One-third standard 19″ width. Two required if no other accessories are mounted.

F

GALVANOMETERS, NULL DETECTORS & POWER SUPPLIES

Introduction F-1
Null Detectors F-5
Amplifiers F-7
Galvanometers F-8
Power Supplies and Batteries F-14



GALVANOMETERS, NULL DETECTORS & POWER SUPPLIES

Leeds & Northrup manufactures a wide variety of galvanometers, detectors and power supplies for use in instrumentation arrangements for various types of measurements. This chapter describes the L&N line of d-c reflecting galvanometers (moving-coil types), d-c self-contained galvanometers (lamp-and-scale and pointer types), electronic d-c and a-c null detectors, d-c indicating amplifiers, and power supplies, as well as galvanometer mounting and reading devices, Ayrton shunts, and other accessory equipment.

Whatever the particular needs of your application, or the precision required, you will find a wide selection of instruments for use either as balance-point detectors in potentiometer or bridge measurements or for calibrated deflection measurements. For special applications, non-standard characteristics can be supplied, usually in a standard construction.

GALVANOMETERS

Galvanometers are electrical instruments used to indicate the presence of small electrical currents. They are used in bridge, potentiometer and other measuring circuits to indicate a "null" when the circuit is balanced. Since the galvanometer is used in these applications to indicate whether or not a current is present, and not necessarily the actual magnitude of the current, the primary requirement for these galvanometers is to show a readable deflection for the smallest current that is significant for a particular measurement.

OPERATION OF SUSPENSION TYPE GALVANOMETERS

Figure 1 illustrates a single suspension-type moving-coil galvanometer which provides very high sensitivity. The galvanometer must be carefully leveled in use so that the coil can rotate freely between the pole pieces of the magnet and the soft iron core. The suspension, made of extremely thin metal ribbon, not only supports the coil but also serves as one current lead, the other lead being an open spiral of similar ribbon which exerts scarcely any force affecting the position of the coil. Pointers are not used with these galvanometers. A mirror is attached to the coil to reflect a beam of light from a fixed source to a scale so that, when the coil is rotated by the interaction of the magnetic field and the current in the coil, a spot of light moves along the scale.

Galvanometers used in portable instruments are of the taut-suspension type in which the coil is supported between spring supports above and below by means of suspensions which are heavier and stronger than those used in the single suspension galvanometers described above. Taut-suspension galvanometers may be provided with pointers to indicate the angular position of the coil.

In the construction of a galvanometer, special care is required to keep magnetic dust or impurities from the coil.

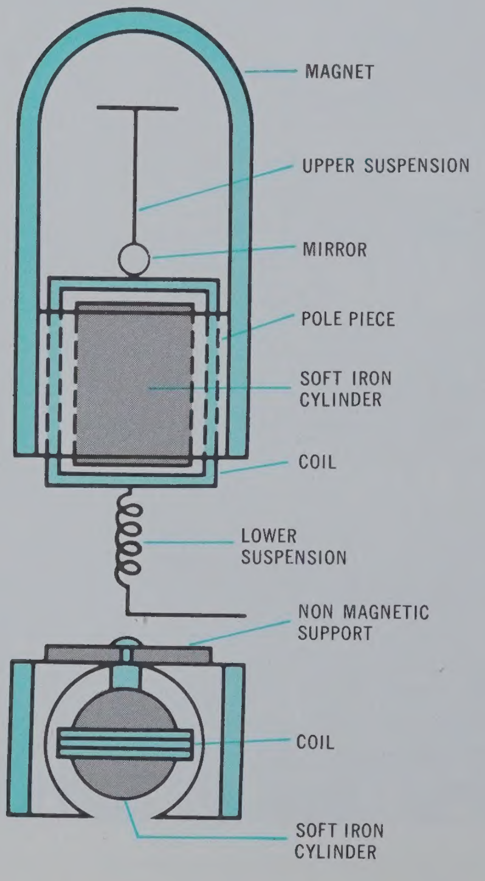


Fig. 1—Construction of a D-C Moving-Coil Galvanometer

GALVANOMETER SELECTION

Leeds & Northrup can provide the type of galvanometer best suited to your particular application. Type HS and Type P moving-coil Reflecting D-C Galvanometers utilize an externally mounted lamp-and-scale or telescope-and-scale for reading deflections. A selection of self-contained d-c galvanometers is also available: Type E Galvanometers have a moving-coil system and self-contained lamp-and-scale reading device; the 2435 Reflecting Galvanometers feature an internal-magnet system and self-contained lamp-and-scale reading device; and the 2340 Galvanometers have an internal-magnet system and pointer.

In choosing a d-c galvanometer, the characteristics of major significance are sensitivity, critical damping resistance and period. Because the exact characteristics desired, especially sensitivity and period, may be in conflict, choice of a galvanometer best suited to a particular application is often a matter of compromise. A brief explanation of the principal characteristics follows; for a more complete explanation of galvanometer principles, construction and application, send for L&N Tech Pub A12.1110, "Moving Coil Galvanometers".

SENSITIVITY—Sensitivity defines the electrical conditions necessary to produce a standard deflection, which is a one-millimeter division on a self-contained scale or, in the case of the high-sensitivity single-suspension type, one millimeter on a detached scale one meter from the galvanometer mirror.

CURRENT SENSITIVITY is the current in microamperes required in a galvanometer coil to produce the standard deflection. Voltage sensitivity can be derived using the current sensitivity.

VOLTAGE SENSITIVITY is the voltage that must be impressed on a circuit, including galvanometer coil and external critical damping resistance (CDRX), to produce the standard deflection*. Voltage sensitivity is equal to the product of current sensitivity and the total resistance required for critical damping.

MICROCOULOMB SENSITIVITY is the charge in microcoulombs per scale division required to obtain a momentary peak deflection when the galvanometer is used ballistically to measure a quantity of electricity.

FLUX-LINKAGE SENSITIVITY is a measure of the change in flux-linkage in maxwell-turns per scale division required to obtain a momentary peak deflection when the galvanometer is used ballistically. Flux-linkage sensitivity may be determined from characteristics of an externally connected pick-up coil and the listed galvanometer characteristics.

The sensitivity which will permit measurement within the required precision is usually determined by simple calculation. It is not desirable to use a galvanometer of sensitivity far greater than the work demands. Excessive sensitivity makes a galvanometer difficult to use because time may be wasted in attempts at too close adjustment, and an unstable zero may result—particularly if unnecessarily high sensitivity results in wide deflections. Also, since increased sensitivity generally results in increased cost of galvanometer construction, a galvanometer which provides ample but not excessive sensitivity is most economical.

DAMPING—The galvanometer system tends to oscillate a long time if the terminals of the galvanometer are open-circuited, but if the terminals are short-circuited, an induced current flows in the direction to oppose motion and the coil moves much more slowly. The galvanometer is then said to be *damped.* If, instead of being short-circuited, the galvanometer circuit is closed through an adjustable resistance, it is possible to control the damping by controlling the value of the induced current. For some particular value of this external resistance, the pointer will return to its zero position in a minimum time without swinging past zero. The galvanometer is then *critically damped* and the value of the external resistance is called the *external critical damping resistance* (CDRX). With an external resistance less than the CDRX, the pointer approaches zero sluggishly and the galvanometer is *overdamped.* If the external resistance is greater than the CDRX the pointer swings past zero and tends to oscillate and the galvanometer is *underdamped.* The most favorable condition of operation of a galvanometer is slightly underdamped, so that it barely swings past zero before coming to rest.

PERIOD—The position at which the pointer or spot of light comes to rest on the scale when no current is passing through the galvanometer coil is called the zero position. If the pointer of an undamped galvanometer is deflected from its zero position and then open-circuited, it tends to oscillate about the zero position. The elapsed time between consecutive passages of the pointer in the same direction through its zero position is called the *period* of the galvanometer. Period is dependent on the physical properties of the suspensions and on the inertia of the suspended system. The stiffer the suspension, the shorter the period, while an increase in mass of the suspended system increases the period. It is usually desirable, in the interest of speed of operation, to design the system so as to make the period short. Stiffening the suspension shortens the period, but this also makes it more difficult for the magnetic forces to deflect the pointer and therefore decreases the sensitivity. The period may be decreased by making the coil lighter. When the period must not exceed a certain value, it is better to specify the period and the damping resistance, leaving the designer to obtain the best sensitivity possible.

GALVANOMETER ACCESSORIES

Leeds & Northrup provides all necessary accessories for use with d-c reflecting galvanometers. These include devices for mounting a galvanometer on a tripod, table or wall, and a choice of reading devices—both lamp-and-scale and telescope-and-scale—for most-precise readings. A lecture-room lamp-and-scale device is available for demonstrating galvanometer deflections to a large group. A choice of straight and curved scales is provided. A curved scale removes the correction arising from the relation between the angle of deflection and its tangent; however, in some cases the error due to the non-radial magnetic field of a galvanometer is just about offset by the tangential error of a straight scale.

A selection of Ayrton shunts in a choice of total resistances is provided for use as current dividers. An Ayrton shunt is used to vary the working sensitivity of a moving-coil galvanometer to make it more suitable for a particular measurement in cases where the circuit to which it is connected does not include provision for a choice of sensitivities. For proper damping of the galvanometer, the total resistance of the shunt should be equal to or slightly greater than the CDRX of the galvanometer. The Ayrton shunt provides an accurately known portion of the total current in a circuit, but it is also useful merely to reduce the galvanometer current temporarily while a bridge circuit is brought slowly to a null-balance position. A large unbalance current which would cause the galvanometer deflection to be off-scale can be partially shunted away from the galvanometer. Subsequent balancing of the bridge circuit reduces the total unbalance current to a value that does not require attenuation by the Ayrton shunt to keep the galvanometer deflection on-scale.

For damping a galvanometer, or for protecting a galvanometer, standard cell or other instrument against excessive current, a choice of damping and current-limiting resistors is available.

A selection of the most commonly used accessories is presented in this catalog. For further information, send for Data Sheet A12.1191.

**Some specifications of foreign manufacturers state voltage sensitivity in terms of the voltage impressed across the galvanometer coil alone.*

ELECTRONIC NULL DETECTORS

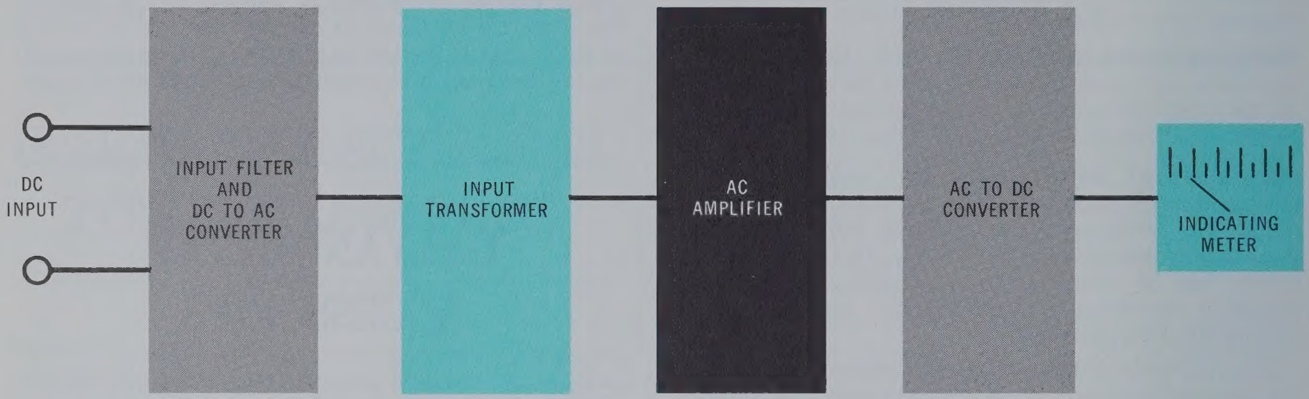


Fig. 2—Electronic Null Detector

An electronic null detector may be used instead of a galvanometer in potentiometer and bridge measurements. Leeds & Northrup can provide electronic null detectors for d-c or a-c detection. The circuit of an electronic d-c null detector performs four functions as diagramed in Figure 2: conversion of the d-c input signal to a-c, amplification of the a-c signal, conversion of the amplified a-c signal to d-c, and indication of the d-c signal on a meter.

Certain advantages and disadvantages must be considered when deciding whether to use an electronic null detector instead of a galvanometer for a specific application. The most important advantages of a null detector are:

1. No loss of indication from an excessive input signal
2. Vibration- and shock-resistance
3. Convenient portability
4. Ease of installation
5. High sensitivity
6. Convenient sensitivity selection
7. Rapid response to changes in input
8. Usable with wide range of source resistance
9. Minimum sensitivity to changes in position

However, null detectors may have certain inherent disadvantages which must be overcome or minimized by careful design and proper application. Unwanted deflections can result from any of the following causes:

1. Sensitivity to stray magnetic and capacitive effects near the instrument.
2. Amplifier noise caused by noisy components such as tubes and resistors
3. Internal thermal emfs
4. Aging of components
5. Zero drift
6. Leakage current
7. Interaction with other line-operated equipment

It is important to evaluate the noise level at the resistance of the circuit in which it will be used. Another important consideration is the amount of zero shift with changes in circuit resistance.

D-C INDICATING AMPLIFIERS

L&N manufactures highly versatile D-C Indicating Amplifiers (for current or voltage) which combine the functions of three instruments in one: a null detector, a direct-reading indicator, and a recorder preamplifier.

POWER SUPPLIES

Leeds & Northrup can provide a wide variety of power sources for your instrumentation applications including guarded and unguarded power supplies, constant-voltage supplies, storage batteries and dry cells.

9838 GUARDED NANOVOLT NULL DETECTOR

Advanced circuitry and construction

5-nV sensitivity per division

Available as bench-top or panel-mounted unit

OFF
AC LINE
CHARGE
BATTERY
OFF
BATTERY TEST
SENSITIVITY
ZERO SUPPRESSION
OUT
IN
LEEDS & NORTHRUP
9838 GUARDED NANOVOLT DETECTOR

For use with highest-precision potentiometers and bridges, this new solid-state nanovolt null detector features 5-nanovolt sensitivity, low noise, superior a-c rejection, and stable zero. The 9838 can be operated from the a-c line or from its internal, rechargeable battery completely isolated from line. All critical components are shock-mounted. Input connections are all copper-to-copper with a specially-designed low-thermal converter. Magnetic and electrostatic shielding is provided throughout separate high- and low-level circuits. This attractively-styled null detector is available in both a bench-top and a panel-mounted version.

2437 HIGH-IMPEDANCE NULL DETECTOR

Metal Oxide Silicon-Field Effect Transistor input chopper

Excellent sensitivity at high impedance

Bench-top, panel-mounted and component models

SENSITIVITY
ZERO
LEEDS & NORTHRUP
2437 D-C NULL DETECTOR

The 2437 is a new, compact null detector featuring an advanced solid-state circuit and large easy-to-read meter, and is available in a variety of models—bench-top, panel-mounted and as a component. The 2437 detector features a MOS-FET input chopper which results in exceptionally stable zero and low noise. The bench-top 2437 is supplied with a carrying handle which can also be used as a stand; the panel-mounted 2437-1 can be used with an accessory mounting rack (see page E-30) for mounting in a 19″ rack; and the 2437-2 can be supplied for field conversion to replace the light-beam galvanometer on L&N portable instruments, or can be specified for inclusion in new instruments.

List No.	Sensitivity (per division)	Noise	Input Impedance	Zero Stability	A-C Rejection (60-Hz)		Response Time (0 to 90%)		Meter	Case	Price
					Common Mode	Normal Mode	Source Resistance	Time			
2437-0-□□* **(bench-top)**	Continuously Adjustable; 0.5 μV below 5K 1.0 μV 5K-50K	Less than 0.5μV peak-to-peak with 50K source resistance	50,000 ohms	Less than 1.0 μV per hour, non-cumulative, after warm-up	$10^7/1$ (140 dB)	30,000:1 (90 dB)	0-1K 10K 50K	1.2 Sec 4.1 Sec 5.2 Sec	25-0-25 μA 1.3″ scale 20 1.6-mm div.	4″ x 6″ x 8″; 3½ lb.	$195.00
2437-1-□□* **(panel-type)**										4¾″ x 6″ x 8″; 2 lb.	195.00
2437-2-□□* **(component-type)**										3″ x 5½″ x 5½″; 1½ lb.	155.00
9838 **(bench-top)**	Continuously Adjustable; 5 nV below 30 ohm 10 nV - 300 ohm 30 nV - 1000 ohm	Less than 10nV peak-to-peak with 300 ohms source resistance	300 ohms	Better than 30 nV, non-cumulative after 1 hour warmup	Greater than $10^8/1$ (160 dB)	Greater than $10^4/1$ (80 dB)	0-100 -1000	2.7 Sec 3.5 Sec	50-0-50 μA 4″ scale 50 2-mm div.	7½″ x 12⅜″ x 7″; 13 lb.	880.00
9838-1 **(panel-type)**										7″ x 19″ x 7″; 10 lb.	880.00

**Power Supply Options for 2437*	*Suffix*	*Add to Price*
No power supply	*00*	—
External batteries (2000 hours operation)	*10*	*$ 5.00*
Mercury-battery power supply (275 hours operation, available for bench-model only)	*20*	*25.00*
Rechargeable battery supply, 120 V, 50/60 Hz (available for bench-model only)	*30*	*75.00*
Rechargeable battery supply, 230 V, 50/60 Hz (available for bench model only)	*31*	*100.00*
Line-powered supply, 120 V, 50/60 Hz	*40*	*40.00*
Line-powered supply, 230 V, 50/60 Hz	*41*	*50.00*

9834 GUARDED D-C NULL DETECTOR

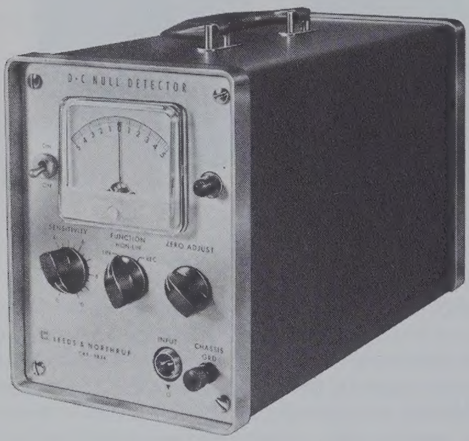
HIGH SENSITIVITY WITH SOURCE RESISTANCES UP TO 100,000 OHMS

Linear and non-linear response

Continuously adjustable sensitivity control

Low noise level, stable zero

Available as portable or panel-mounted unit



The 9834 Electronic Null Detector is a rugged, compact, line-operated instrument for use in precision d-c measurement circuits. It has faster response than galvanometers and simple meter readout with provision for remote indicating or recording. It has many applications where a high-sensitivity null detector is required. The function switch provides a linear mode for interpolation of "go", "no-go" applications, and a non-linear mode which absorbs large inputs (which would normally drive the meter off-scale) while retaining the desired sensitivity near the null-point. The instrument features a guarded circuit and floating chassis, can operate at any angle and does not require shock-absorbing feet.

9844-☐ A-C NULL DETECTOR

HIGH SENSITIVITY WITH SOURCE IMPEDANCES UP TO 100,000 OHMS

Knob-selected choice of five sensitivities

Non-linear response provides maximum sensitivity at null point

Plug-in filter units provide selection of frequencies

The unusual versatility of the 9844 A-C Null Detector is made possible by plug-in, interchangeable filter units which permit the detector to operate on any of the specified frequencies of 50, 60, 400, or 1000 hertz (filter units for other frequencies are available on special order). This rugged, portable, line-operated detector is used with precision a-c bridges, electrolytic-conductivity bridges, current- and potential-transformer test sets, Schering bridges, etc. Features contributing to convenience and accuracy of operation include five choices of sensitivity, a short period and low noise level. The instrument is housed in a gray metal case with durable vinyl finish and carrying handle.

List Number	Maximum Sensitivity		Period	Resistance or Impedance, Ohms		Noise	Meter Response	Power	Case	Price
	For Source Resistance or Impedance, Ohms	Sensitivity, μV/mm		Input	External					
✗ 9834 (Portable) 9834-1 (Panel-mounted)	Up to 2,000 2,000 to 20,000 20,000 to 50,000 50,000 to 100,000	0.067 0.10 0.20 0.40	Less than 2 sec for source resistances up to 1,000 ohms, increasing to 4 sec at 100,000 ohms	25,000	Up to 100,000	Less than 0.1 μV peak-to-peak	Linear: 2% of full scale for 80% deflection either side of scale 0. Non-linear: Essentially linear for 20% deflection either side of scale 0.	120 V 60 or 50 Hz	9834: 9¼″ x 6½″ x 14″; 9834-1: 8″ x 6¼″ x 12¾″; weight 16 lb	$325.00
9844-☐*	Up to 20,000 20,000 to 50,000 50,000 to 100,000	0.2 0.4 0.8	Less than 1 sec for 50% of full scale unbalance	10,000	Up to 100,000	Less than 0.1 μV peak-to-peak	Non-linear. Essentially linear from 0 to approx. 60% of full scale. Amplifier saturates completely at about 85% of full scale.	120 V 60 or 50 Hz	9¼″ x 6½″ x 14″; weight 16 lb	450.00

* *Specify input signal frequency by adding suffix "-50", "-60", "-400" or "-1000" to the list number. Plug-in filter units for other than specified frequency, between 25 hertz and 20 kHz, can be separately ordered.*

9835 STABILIZED D-C INDICATING AMPLIFIER (Voltage)
9836 STABILIZED D-C INDICATING AMPLIFIER (Current)

PERCENT OF RANGE
MICROVOLT INDICATING AMPLIFIER
LEEDS & NORTHRUP CO.
NON-LINEAR
LINEAR
RECORDER
RANGE
SHIELD
INPUT
D-C MICROVOLTS
LINE
ON
OFF

FOR LOW-LEVEL CURRENT OR VOLTAGE MEASUREMENTS

Applicable as null detector, direct-reading indicator, or recorder preamplifier

Linear and non-linear deflection

Inherently stable zero and gain

Magnetic and electrostatic shielding

Specifically designed for low-level d-c measurements of voltage or current, the 9835 and 9836 Stabilized D-C Indicating Amplifiers are widely used in both research and production testing. Applications include: the output measurement of thermocouple circuits, strain gauges, bolometers, phototubes, ionization chambers, scintillation counters; measurement of diffusion currents; and in bridge and potentiometer assemblies. Highly versatile, these amplifiers combine the functions of three instruments in one: as a null detector, they provide a short period of only two or three seconds, depending upon source resistance; as a direct-reading indicator, they have multiple switch-selected ranges to indicate microvolts or pico-amperes; as a recorder preamplifier, they can extend the application of standard Speedomax G, H or W Recorders to low-level d-c measurements. They feature inherently stable zero and gain, and switch selection of linear or non-linear scale deflection (40 times normal input is required to produce half-scale deflection on non-linear).

List Number	Ranges	Amplifier Accuracy*	Source Resistance	Response Time	Equivalent Noise Level	Input Impedance	Case**	Price
9835-A (Zero-left meter)	Six, switch-selected, from 0 to 50 µV, to 0 to 2000 µV	±(0.4% of range +0.5 µV)	10,000 ohms, maximum	Within 1% of balance: 2 seconds for 2000 ohms max source resistance, 3 seconds for source resistances up to 10,000 ohms	Less than 0.15 µV	Steady State Conditions: 12 megohms approximate. Transient Conditions: Approximately 12 megohms resistance shunted by 220 µF of capacitance, the combination in series with 2000 ohms.	10¾″ x 19⅜″ x 8⅜″; weight 34 lb	$715.00
9835-B (Zero-center meter)	Six, switch-selected, from −25 to +25 µV, to −1000 to +1000 µV							
9836-A (Zero-left meter)	Eleven, switch-selected, from 0 to 1×10^{-9} ampere to 0 to 2×10^{-6} ampere	±(0.5% of range +20 pA) for source resistance 1 megohm or greater; ±(0.8% of range + 20 pA) for source resistance from 0.1 to 1 megohm	0.1 megohm, minimum	Within 1% of balance: from less than 1.5 seconds to less than 3 seconds, depending upon range and source resistance	±0.5 µV maximum	Steady State Conditions: 1000 ohms, approximate. Transient Conditions: Approximately 250,000 ohms resistance shunted by series combination of 1000 ohms resistance and 109,000 henries inductance.	10¾″ x 19⅜″ 8⅜″; weight 34 lb	950.00
9836-B (Zero-center meter)	Eleven, switch-selected, from −5 to $+5 \times 10^{-10}$ ampere to −1 to +1 ampere							

**Applies to amplifier only. For indicated readings, add ±1% of full-scale meter value.* ***Removable from case for mounting on relay rack.*

2340 D-C POINTER GALVANOMETER

A GENERAL-PURPOSE GALVANOMETER
WITH MODERATE SENSITIVITY

Self-contained, compact unit

Interchangeable systems easily installed

Wide range of viewing angles

Completely self-contained in one compact, space-saving unit, the 2340 Pointer Galvanometer has many applications in education and research where a sensitive detector is required. These galvanometers have interchangeable internal-magnet systems permitting a choice of sensitivities. The new wrap-around clear plastic window provides excellent visibility of scale and pointer over a wide range of viewing angles. The instrument is housed in a molded impact-resistant gray plastic case.

2435 REFLECTING GALVANOMETER LAMP AND SCALE

AN INTERNAL-MAGNET
GALVANOMETER SYSTEM WITH
MODERATELY HIGH SENSITIVITY

Self-contained, compact unit

Optional viewing—horizontal and vertical scales

Interchangeable systems for flexibility of operation

Combining moderately high sensitivity with excellent visibility and operating convenience, the 2435 Reflecting Galvanometer permits optional viewing of either the horizontal scale on the top plate, or the vertical scale on the front of the case. Packaged in a compact, space-saving, impact-resistant plastic case, the assembly consists of an internal-magnet galvanometer system and a lamp-and-scale reading device. Deflections from null are indicated, on either glass scale, as a rectangular light-band split by a sharply defined hairline. Two knobs on the top of the case provide coarse and fine zero adjustment.

2430 TYPE E GUARDED D-C GALVANOMETER

0 1 2 3 4 5 6 7 8 9 10
LEEDS
NORTHRUP

A HIGH-SENSITIVITY GALVANOMETER FOR GENERAL USE

Self-contained, compact unit

Guarded construction

Primary and secondary light spots

Vibration-resistant design

Interchangeable systems easily installed

Combining high sensitivity with operating convenience, the 2430 Type E Galvanometer offers the advantage of a rugged galvanometer system and a lamp-and-scale reading device assembled in one compact unit. Deflections from null are indicated on a translucent scale by movement of a primary light spot split by an index line. A secondary light spot, with 1/10 motion of the primary spot, moves to show the direction of the deflection, which is particularly helpful when the primary goes off scale. Circuit-guarding features minimize the effects of humidity and surface contamination. Minor system vibrations are damped by a unique arrangement consisting of a viscous damper coiled around the suspensions, one above and one below the moving coil. Severe vibrations can be damped by substituting special shock-absorbing feet for the standard ones. Four different interchangeable galvanometer systems are available for the Type E to provide flexibility of application.

List Number	Sensitivity* (Per Scale Division)	Period (Sec)	Resistance (Ohms)		Scale	Lamp Requirements	Case	Price
			External Critical Damping	System				
2430-a 2430-c 2430-d 2430-e	0.5 μV 0.005 μA 0.0005 μA 0.001 μA	3.0 2.5 3.0 3.0	30 to 90 300 to 500 15,000 to 30,000 5000 to 8000	10 25 550 175	100 1-mm divisions 5-0-5 and 0-10	120 V, 60 or 50 Hz	6¼″ x 13⅝″ x 9¼″ weight approx. 14 lb	$225.00
2435-a 2435-b 2435-c 2435-d	0.1 μA 0.06 μA 0.025 μA 0.010 μA	4.0 3.0 3.0 3.5	35 100 1000 10,000	35 40 90 500	50 1-mm divisions 25-0-25	120 V, 60 or 50 Hz	3 27/32″ x 7 9/32″ x 5¼″ weight approx. 3 lb	130.00
2340-a 2340-b 2340-c 2340-d	1.0 μA 0.6 μA 0.25 μA 0.1 μA	4.0 3.5 3.5 4.0	35 100 1000 10,000	35 40 90 500	20 1-mm divisions 10-0-10	--	2¾″ x 5⅜″ x 5 3/16″ weight approx. 1 lb	75.00

**Sensitivities are at least as high as stated; other characteristics, within 20%.*

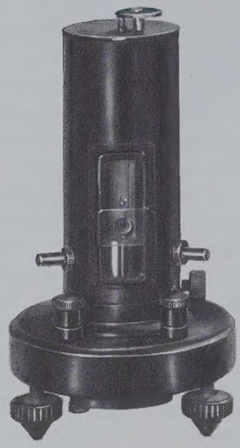
D-C MOVING-COIL, REFLECTING GALVANOMETERS

Leeds & Northrup offers a variety of moving-coil, reflecting-type galvanometers, with a wide selection of sensitivities, periods, and critical damping resistances.

The suspensions of these galvanometers are thin rolled strips of copper, or 24K or 14K gold, and provide high tensile strength and low suspension resistance relative to the restoring constants.

To provide for deflection readings with either a telescope-and-scale or a lamp-and-scale reading device, all of these galvanometers have a plane mirror and a lens of 1-meter focus. Easily removable, this lens can be quickly replaced with others of different focal lengths. L&N galvanometer mounting and reading devices are described on pages F-12 and F-13.

2290 TYPE HS GALVANOMETER



FOR MAXIMUM CURRENT SENSITIVITY
AVAILABLE IN A MOVING-COIL
GALVANOMETER

Easily interchangeable lens

Both coarse and fine zero adjustments

Adjustable pole for high sensitivity

Specialized construction, including adjustable polepieces, provides the maximum current sensitivity obtainable in a moving-coil galvanometer. The galvanometer is equipped with a ⅜″ plane mirror and a detachable lens of 1-meter focus, and has coarse and fine zero adjustments.

Type	List Number	Sensitivity* (Per mm at 1 meter)	Period (Sec)	Resistance (Ohms)		Dimensions	Price
				External Critical Damping	System		
HS	2290	0.000 01 μA	40	100,000	800	10″ x 5½″ (dia.) weight 4 lb	$800.00
HS	2284-a	0.5 μV	1.5	40	21	10″ x 5½″ (dia.) weight 4 lb	350.00
	2284-b	0.05 μV	7	10	16		350.00
	2284-c	0.1 μV	5	20	16		350.00
	2284-d	0.1 μV	5	50	25		350.00
	2284-e	0.005 μA	1.5	1200	300		350.00
	2284-x	As specified	—	—	—		P.O.R.
HS	2285-a	0.1 μV	7.5	25	17	10″ x 5½″ (dia.) weight 4 lb	250.00
	2285-b	0.2 μV	5	40	16		250.00
	2285-d	0.0003 μC**	27	50,000	700		400.00
	2285-e	0.003 μC**	25	600	12		400.00
	2285-f	0.000 04 μA	20	70,000	800		250.00
	2285-g	0.0003 μA	7	10,000	525		250.00
	2285-h	0.008 μA	1.5	2500	515		210.00
	2285-j	0.0006 μA	10	550	55		285.00
	2285-x	As specified		—	—		P.O.R.
P	2239-a	0.014 μA	8	10,000 to 100,000	125	6¼″ x 14″ x 2¼″ weight 6 lb	130.00
	2239-b	0.001 μA	14	10,000 to 25,000	1000		130.00
	2239-c	1.5 μV	12	165	35		P.O.R.
	2239-d	0.002 μC**	26	10,000	2000		130.00
	2239-e	0.011 μC**	24	270	60		130.00
	2239-f	0.0002 μA	18	46,000	8000		130.00

**Sensitivities are at least as high as stated; other characteristics, within 20%. Microvolt sensitivities are for critical damping resistance in series. System resistance includes suspensions.*

***Ballistic sensitivities given.*

2284 TYPE HS GALVANOMETER

FOR EXTRA-HIGH VOLTAGE SENSITIVITY
WITH RESPECT TO OTHER
CHARACTERISTICS

Easily interchangeable lens

Both coarse and fine zero adjustments

A choice of extremely high voltage sensitivities with respect to other characteristics is provided. The galvanometer is fitted with a ¼″ plane mirror and a detachable lens of 1-meter focus, and has both coarse and fine zero adjustments.

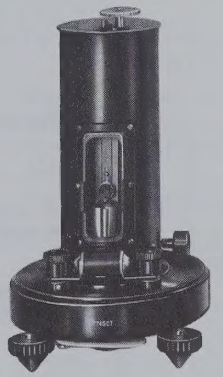
2285 TYPE HS GALVANOMETER

FOR EXTREMELY HIGH SENSITIVITY

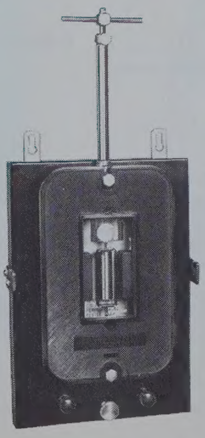
Easily interchangeable lens

Both coarse and fine zero adjustments

A choice is available of extremely high sensitivities, combined with other desirable characteristics, in voltage-sensitive, current-sensitive and ballistic types. This galvanometer has a plane mirror (⅜″ in 2285-a, -b, -f, -g and -h; ½″ in 2285-d and -e) a detachable lens of 1-meter focus, and provision for coarse and fine zero adjustments.



2239 TYPE P GALVANOMETER



FOR MODERATE SENSITIVITY IN
EDUCATIONAL LABORATORIES

Internal parts visible for demonstration

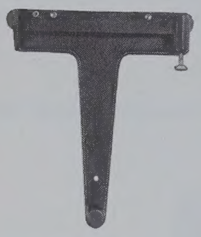
Simple yet sturdy construction makes internal parts both visible and accessible for maximum educational usefulness. Suspensions are easily removable, and coil and mirror are readily changed. A choice of characteristics is available, and 2239-d and -e are suitable for ballistic measurements. The galvanometer is equipped with a ⅝″ plane mirror and a detachable lens of 1-meter focus.

ACCESSORIES AND PARTS FOR GALVANOMETERS

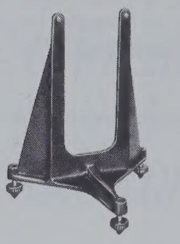
GUIDE TO APPLICABLE MOUNTING AND READING DEVICES

Galvanometer		Mountings					Telescope & Scale					Lamp & Scale Reading Devices			
		2126	2127	2147	2146	2162	2148	2149	2170	2196	2195	Lecture-Room	2100	2111	2112
Type P	2239	*	*						*	*	*	*	*	*	
Type HS	2284			*	*	*	*	*		*	*	*	*		*
	2285			*	*	*	*	*		*	*	*	*		*
	2290			*	*	*	*	*		*	*		*		*

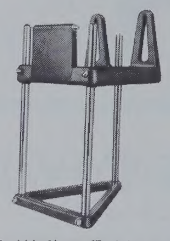
GALVANOMETER MOUNTINGS



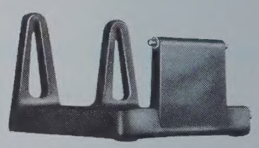
2127 Wall Mounting, with leveling screws $30.00



2126 Table Tripod, with leveling screws $25.00



2147 Wall or Table Bracket $50.00



2146 Wall Bracket $30.00 (Same as 2147, but without legs)

Also: 2162-A1 Julius Suspension Assembly (not illustrated) $320.00

AYRTON SHUNTS

List Number	Resistance (Ohms)	Multipliers	Ratio Limit of Error	Dimensions	Price
2664	100,000	1, 0.1, 0.01, 0.001, 0.0001, 0,00001, 0 and infinity.	±0.1%	6⅞″ (l) x 6½″ (w) x 5¼″ (h). Gray metal case.	$100.00
2665	40,000	1, 0.1, 0.01, 0.001, 0.0001, 0 and infinity.			90.00
2615	25,000				80.00
2666	10,000				90.00
2667	3,000				90.00

2664

DAMPING RESISTORS

Part Number	Name	Use	Resistance, Ohms	Limit of Error	Price
R-506-N-2	Resistor	For damping a galvanometer, or for protecting a galvanometer, standard cell, or other instrument against excessive current. In transparent case with metal top, provided with two insulated, flexible leads approximately 5″ long.	Specify any value between 10 and 10,000 ohms.	±0.1%	$19.00

R-506-N-2

TRANSFORMERS AND CURRENT-LIMITING RESISTORS

Item	Use	Power Source	List Number	Price
Transformer	Produces 6-volt output for operating lamp in 2100, 2111 and 2112 Lamp and Scales	115 volts, 50/60 hertz	10609	$ 6.95
		115 volts, 25 hertz	10610	8.70
		230 volts, 60 hertz	Std 1178-26	29.00
Resistance Unit	For operating lamp in 2100, 2111 and 2112	115 volts, d-c	10766	16.95

UNMOUNTED CARDBOARD SCALES FOR READING DEVICES

Part Number	Divisions, mm	Graduations	Price
Std 884	500	0-50 (inverted figures)	$2.20
Std 885	500	0-50 (upright figures)	1.80
Std 875*	500	25-0-25 (inverted figures)	1.50
Std 888	500	25-0-25 (upright figures)	3.30
Std 881	500	Unnumbered	0.70
Std 882	1000	0-100 (inverted figures)	4.80
Std 883	1000	50-0-50 (inverted figures)	6.10

**Supplied as standard in telescope-scale assemblies.*

TELESCOPE AND SCALE READING DEVICES

WITH ATTACHABLE BRACKET

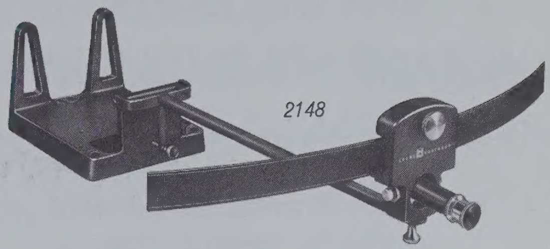
2148 TELESCOPE, ARM AND CURVED SCALE WITH ATTACHABLE WALL BRACKET Consists of (a) 2197 Telescope, unmounted, 4 diameters magnification; (b) Std 3375-N Curved Scale, Holder and Friction Drive Assembly (includes Telescope Mounting, Std 10077 Metal Scale Holder and Std 875 Printed Scale); (c) PI-156 Arm, for scale distance of ½ meter; and (d) 2146 Wall Bracket (see "Galvanometer Mountings"). $174.00

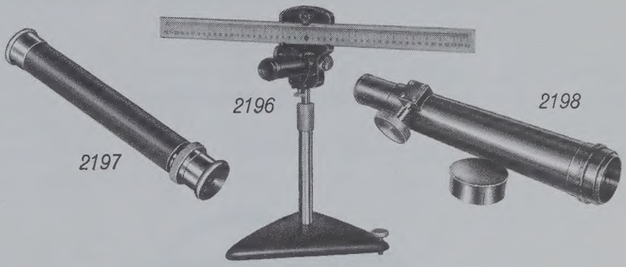
2149 TELESCOPE, ARM AND CURVED SCALE WITH ATTACHABLE WALL OR TABLE BRACKET Same as 2148, except: (d) 2147 Wall or Table Bracket (see "Galvanometer Mountings"). $194.00

SEPARATE

2196 TELESCOPE AND SCALE Consists of (a) 2198 Telescope, unmounted, 12 diameters magnification, with focusing range 0.6 meter to infinity; (b) Std 3375-AE Straight Scale, Holder and Friction Drive assembly (includes Telescope Mounting, Std 10078 Metal Scale Holder and Std 875 Printed Scale; and (c) Tripod Base with leveling screws and altitude and azimuth adjustments. $225.00

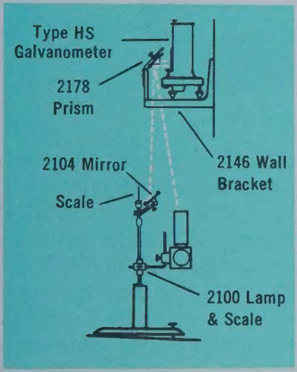
2195 TELESCOPE AND SCALE Same as 2196, except: (a) 2197 Telescope, unmounted, 4 diameters magnification, and (b) Std 3375-T Straight Scale Assembly. $100.75



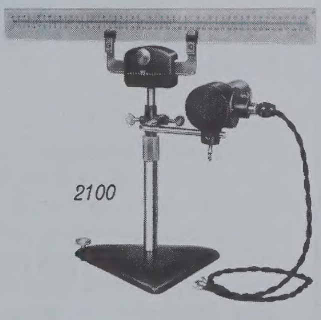


Also: 2170 Telescope, Arm & Curved Scale attachable to galvanometer (not illustrated), $116.00

LAMP AND SCALE READING DEVICES

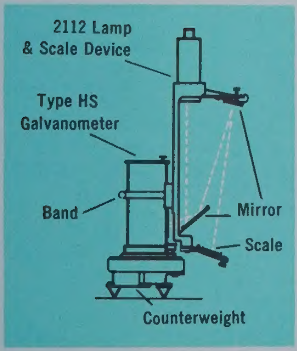


Vertical Arrangement

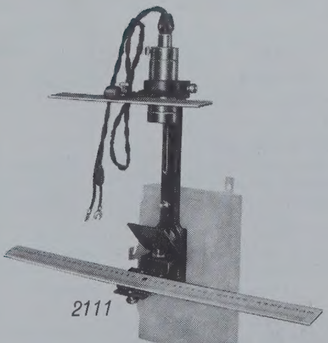


SEPARATE

2100 LAMP AND SCALE Consists of (a) Std 309 Etched Glass Scale, ½ meter, with 500 1-mm divisions, marked 0-50 and 25-0-25 (where 0-50 marking only is required, specify Std 309-1); (b) 2099 Illuminating Device and Brackets, with 6 V, 21 cp lamp (Std 2544: Mazda No. 1130); and (c) Tripod Base with leveling screw. Transformer or current-limiting resistor for the lamp power supply must be ordered separately, and is listed on the opposite page. For vertical projection (with galvanometer mounted above the 2100 Lamp and Scale), it is also necessary to order as separate items a 2104 Mirror, attachable to the 2100 assembly, and a 2178 Prism, having a bracket for mounting in front of the galvanometer. (For a 2284, or 2285 Galvanometer mounted in a 2162 Julius Suspension, specify a 2178-S Prism.) $100.00



2112



ATTACHABLE GALVANOMETER

(For Null Measurements)

2111 LAMP AND SCALE *For mounting on front of 2239 Galvanometer.* Consists of a cast mounting, an illuminating device with a 6 V, 21 cp lamp (Std 2544: Mazda No. 1130), mirrors, and a 2180-14 Scale and Scale Holder with Rack Plate Assembly. The 2180-14 includes a Std 888 Printed Scale; if other calibrations are required, specify Std 885 or Std 881 Printed Scale as a separate item. Transformer or current-limiting resistor for the lamp supply must be separately ordered, and is listed on the opposite page. $200.00

2112 LAMP AND SCALE *For mounting on cylindrical galvanometers (2284, 2285, etc.).* Same as 2111 above, except that it includes a 2111-P1 Band and Counterweight to adapt the reading device to these detectors. $220.00

Also: Lecture-Room Lamp and Scale Assembly (not illustrated), P.O.R.

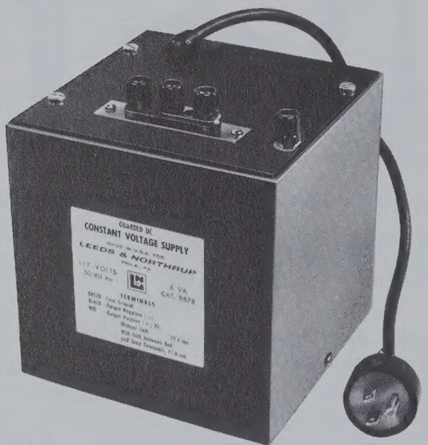
9878 GUARDED CONSTANT-VOLTAGE SUPPLY

PROVIDES STABLE, LOW-NOISE CURRENT SUPPLY FOR HIGHEST PRECISION POTENTIOMETERS

Completely guarded

Electrostatically shielded

Line isolation



A fully-guarded constant-voltage supply for use with high-precision null-balance potentiometers such as the 7555 and 7556, this precision unit replaces the wet or dry batteries usually used. The unit produces a constant d-c output voltage to a constant load regardless of small line voltage and temperature variations. Features include completely guarded and electrostatically-shielded construction, low temperature coefficient (less than 2 ppm per degree C), and exceptional stability (0.5 ppm over a ten-minute period after a three-hour warm-up).

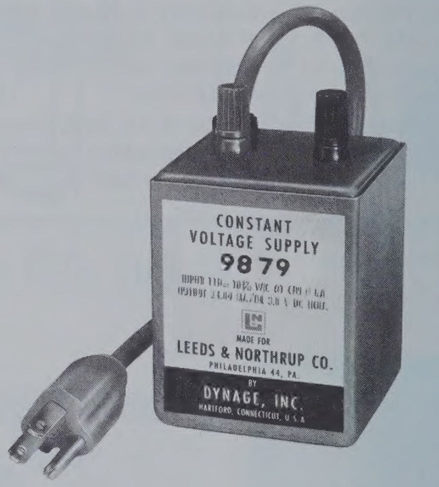
9879 GUARDED D-C CONSTANT-VOLTAGE SUPPLY

REPLACES DRY CELL OR STORAGE BATTERY IN POTENTIOMETER STANDARDIZING CIRCUIT

Eliminates need for frequent standardization

Shielding from electrostatic charges

Guarded

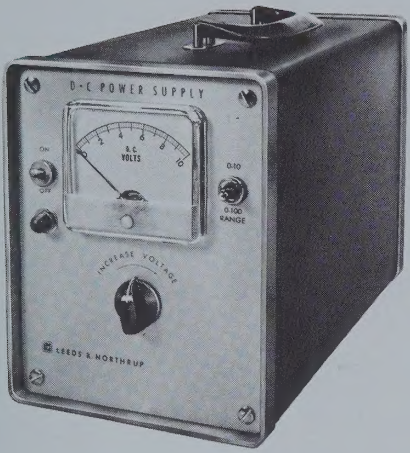


Designed to minimize current drift between restandardizations of Type K Potentiometers, the 9879 (and 099034) Constant-Voltage Supply replaces the storage batteries or dry cells normally used. Operating from line voltage, it delivers a constant d-c voltage to the potentiometer measuring circuit. The potentiometer must be standardized when the power supply is initially energized, and then only occasionally checked during use. Shielding is provided by a steel case and grounded 3-conductor line cord.

List No.	Input	Output	Stability					Isolation		Case	Price
			Output Regulation	Temp. Coefficient	Max. Ripple	Drift Stability	Max. Random Noise	AC	DC		
9878	117 V ± 10%, 50/60 Hz, 6 VA	2.0 V d-c ± 2% at 12.1 mA (for 7555); 2.0 V d-c ± 2% at 11 mA (for 7556)	0.0005% max. immediate change of output per 10 V line change; 0.001% max. final change of output per 10 V line change*	Less than 0.0002%/°C*	0.001% RMS at 60 and 120 Hz	0.01 % per year 0.001% per 24 hrs 0.0002% per hr** 0.00005% per 10 min.**	Less than 0.0003% (0.6 Hz to 2 kHz)	Less than 8 x 10^{-9} amperes	Guard to ground greater than 10,000 megohms	6″ x 6″ x 7¼″; weight, approx. 5 lb	$375.00
9879	117 V ± 10%, 50/60 Hz, 3 VA	2.0 V d-c ± 2% at 12 mA	0.0005% max. immediate change of output per 10 V line change; 0.001% max. final change of output per 10 V line change*	Less than 0.0005%/°C*	0.001% RMS at 60 and 120 Hz	0.01% per year 0.001% per 24 hrs 0.0005% per hr*** 0.0002% per min***	Less than 0.0003% (0.6 Hz to 2 kHz)	Less than 25 nA, RMS	Guard to ground greater than 500 megohms at 85% relative humidity	2-9/16″ x 2-9/16″ x 4-7/32″; weight approx. 1½ lb.	$145.00
099034		2.0 V d-c ± 2% at 24.44 mA									

**At 20-30 degrees C. **After 3-hour warmup. ***After 1-hour warmup.*

9876 D-C POWER SUPPLY



Large easily-read meter
Any output from 0 to 100 volts
Available as portable or panel-mounted unit

These line-operated bridge-voltage supplies are specifically designed for use with general purpose Wheatstone bridges such as the 4735. Completely self-contained, these d-c power supplies are designed for mounting on a panel or in an optional carrying case.

List No.	Input	Ranges	Max. Current	Meter Accuracy	Case	Price
9876 & 9876-1*	120 V, 50/60 hertz	0 to 10 V	800 mA to 6 V, 100 mA to 10 V	± 0.2 V	9876: 6½″ x 9¼″ x 13½″; weight, approx. 11 lb	$225.00
		0 to 100 V	20 mA	± 2.5 V	9876-1: 6¼″ x 8″ x 12″; weight, approx. 8 lb	

**Panel-mounted.*

BATTERIES

7597 WILLARD LOW-DISCHARGE BATTERY

Characterized by low self-discharge and resultant long-life, this battery is designed for use with low current-drain applications. The loss of capacity due to local action in the usual type of storage battery has been minimized. It is superior to any of the usual lead cells in regard to stability of voltage, drift and freedom from maintenance. The 7597 has a temperature coefficient of about 0.01% per degree C, and drift of 15 mV per hour after reaching maximum stability.

List No.	Type	Rating	Price
7597	DD-5-1	2 volts, 200 ampere-hours	$23.20
Std 986	Type D, Eveready No. 950	1.5 volt	0.25
Std 2233	No. 6 Dry Cell with Spring Clips	1.5 volt	1.40
Std 2233-1	"Little Six" Ignition Type Battery, Burgess No. 4FH	1.5 volt	1.40
Std 2233-2	"C" Battery, Burgess Battery Co. No. 2370	4.5 volt	3.30
Std 2233-4	Nominal No. 250 Dry Instrument Carboncell Max. continuous load, 200 mA	1.5 volt	9.05
Std 2233-7	Eveready No. 482 Battery	45 volt	6.10
Std 2233-8	Burgess No. 5540 Battery	7.5 volt	2.80
Std 2233-9	Burgess No. 4156 Battery	22.5 volt	2.55
Std 2233-10	Burgess 4-F-2-H Twin-Six Telephone Battery	3 volt	3.00
Std 2233-11	Burgess 4-F-3-H Tri-Six Telephone Battery	4.5 volt	6.10
056023	Flashlight Type, No. 912 Eveready	1.5 volt	0.25
056025	Alkaline Type Dry Cell (ASA "D")	1.5 volt	1.50
056028	Nickel Cadmium Battery N78, Eveready	1.25 volt	28.00
056029	Dry Cell, No. 915-AA Eveready	1.5 volt	0.25
056050	Burgess Battery Co.	1.35 volt	1.10
56-1-0-1	Mallory Mercury Cell, Type RM-42	1.34 volt	3.00
56-1-0-3	Eveready No. 751	1.5 volt	1.90
56-1-0-4	Battery, Burgess 2F2H	3 volt	3.20

D-C NULL DETECTOR
SENSITIVITY
FUNCTION
ZERO ADJUST
LEEDS & NORTHRUP
INPUT
CHASSIS GRD
LEEDS & NORTHRUP

G

PRIMARY ELEMENTS, KEYS AND SWITCHES

Introduction G-1
High-Precision Thermocouples and Thermometers G-3
Special-Purpose Thermocouples and Thermometers G-6
Liquid Analysis G-8
Keys and Switches G-12

PRIMARY ELEMENTS & ACCESSORIES

FOR LABORATORY USE

This chapter presents a selection of L&N primary elements—thermocouples, resistance thermometers, pH electrodes and conductivity cells—for precise laboratory measurements. These devices translate temperature, pH and electrolytic conductivity into electrical terms so that they can be measured by means of appropriate potentiometers or bridges.

Because these elements are no less important than the measuring instruments employed with them, Leeds & Northrup devotes extensive research, in both materials and manufacturing techniques, toward their continuing improvement. We are thereby prepared to take overall responsibility for the performance of the measuring system.

This chapter describes the more commonly used elements. However, we can recommend, or build to your requirements, a primary element of suitable precision for any of a wide variety of measurable quantities encountered in laboratory or test work. For such specialized requirements, simply outline your problem to your nearest L&N office, or write us at Philadelphia.

Also included in this chapter is a selection of L&N switches and keys specially designed for laboratory applications.

THERMOCOUPLES

For temperature measurements made with potentiometers, L&N can provide assembled thermocouples and extension wires with which to connect them. We also carry a large supply of standardized and tested thermocouple wire in various sizes, and parts such as insulators, connectors, heads, etc.

Noble-metal and base-metal thermocouples are available in appropriate wire sizes and in choice of lengths. A thermocouple may be used unprotected, or mounted in a suitable protecting tube or well, chosen according to the pressure, temperature and composition of the medium to which it will be exposed.

For unusual requirements, special thermocouples, many of which utilize our standard wires and parts, can be supplied at a cost little greater than that of standard ones.

This chapter lists platinum, 10% rhodium-platinum thermocouples for laboratory standards, specialized iron-constantan thermocouples for body-temperature measurements and selected wires for making platinum, rhodium-platinum thermocouples. For many laboratory measurements, appropriate industrial-type thermocouples such as the miniature pipe-types may be used. Complete listings of assembled noble-metal and base-metal thermocouples, thermocouple elements (wires and insulators), and standard wire, insulators, tubes, etc. are described in a separate catalog[1]. A detailed discussion of the theory of thermocouple measurements is also available[2].

For intercomparison of laboratory standard thermocouples or calibration of working standard thermocouples, L&N can supply a Checking Furnace, equalizing blocks (see chapter on Standards) and a Direct-Reading Thermocouple Comparator (see chapter on Comparators). Practical guidance on calibrating thermocouples is found in our folder on thermocouple checking[3].

RESISTANCE THERMOMETERS

For use with temperature bridges, L&N can provide a choice of resistance thermometers, constructed of platinum, nickel or copper wire specially treated, wound and mounted for highest reproducibility.[4]

This chapter lists high-precision platinum resistance thermometers, recommended for use as temperature standards. Platinum wire, universally accepted as maintaining its calibration better than any other material, is used for the temperature-sensitive elements of our most accurate thermometers. Wound and annealed to minimize the effects of internal and external strains, these thermometers, if properly maintained, exhibit an unusually high degree of stability over a period of years. Information on calibration techniques is available in an L&N technical publication[5].

Also listed are Thermohm® assemblies for wet- and dry-bulb measurements and for temperature difference determination.

For many laboratory applications, such as environmental controls, 100-ohm copper resistance thermometers (Thermohm detectors) are most suitable. Data Sheets are available for a complete description of platinum Thermohm detectors[6], and for copper and nickel Thermohm detectors[7].

LIQUID ANALYSIS

For use with a-c bridges for measurement of electrolytic conductivity, L&N provides a selection of conductivity cells, including Jones conductivity cells for highest precision, and other types of cells for general laboratory use. Also listed are dip-type cells for use with L&N portable indicators. The nature and location of the measurements to be made govern the general form of cell to be used. In addition, an estimate of the conductivity or specific conductance of the solution to be measured is helpful in the selection of a cell having suitable characteristics.

A selection of L&N pH electrodes is presented, including glass, metal and reference electrodes, and a miniature pH electrode assembly. Accessories, such as holders and buffer solutions, are also listed.

The Polarotron P-40 Dropping Mercury Electrode is recommended for use with the L&N Electro-Chemograph® for ultimate accuracy and convenience in polarographic analysis.

KEYS & SWITCHES

This chapter also lists a selection of rotary switches for thermocouples (8248) and Thermohm detectors (8249), high-quality Type 31 and Type 01 Rotary Switches for a wide variety of applications requiring low and stable contact resistance and low thermals, and tapping keys and pinch-type switches for use in instrumentation setups.

Toggle-type and push-button switches, primarily for routine service, can also be supplied.

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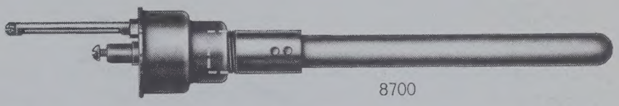
1. *Catalog D1.1001, "Thermocouples . . . Assemblies, Parts, Accessories".*
2. *Tech Pub D1.1000, "General Principles of Thermoelectric Thermometry" by D. I. Finch.*
3. *Folder A1.1121, "Calibrating & Checking Thermocouples in Plants & Laboratories".*
4. *Tech Pub A1.2102, "Recent Trends in Resistance Thermometry", by H. L. Daneman and G. C. Mergner.*
5. *Tech Pub A1.2101, "Calibration Techniques for Precision Platinum Resistance Thermometers", by D. A. Robertson and K. A. Walch.*
6. *Data Sheet D1.2111, "Thermohm Assemblies, Platinum Industrial Type".*
7. *Data Sheet D1.2112, "Thermohm Detectors and Assemblies, Copper and Nickel Industrial Type".*

PLATINUM, 10% RHODIUM-PLATINUM THERMOCOUPLES

FOR USE AS LABORATORY STANDARDS*

For laboratory measurements of temperature using potentiometer instruments, platinum, 10% rhodium-platinum thermocouples are available. A National Bureau of Standards Report of Calibration or Test, or an L&N Report, can be provided for any of these thermocouples at additional charge. (See page G-5.)



8700

Std. 780-B 8710-K2025 illustrated on page B-22

ORDERING

To order either the 8710-K2002-☐-☐ for general high-precision applications or the 8710-K2025-☐-☐ for use in a thermocouple checking furnace (in an equalizing block), add to the List Number (1) the length of the thermocouple (protecting tube) in inches, followed by (2) the length of the wire extensions to reach the ice bath, in

The 8700-☐, for measurements of moderate precision, has a mercury thermometer in the head for reference-junction temperature. It is specified by adding the desired length of the thermocouple (protecting tube) in inches as a suffix to the List Number. For a replacement element, specify Std 780-F-☐.

The Std 780-B-☐ is a high-precision thermocouple supplied without a protecting tube. Add the desired length of the thermocouple in inches as a suffix to the List Number. Additional lengths of thermocouple wire, sufficient to reach the ice bath, should be specified. A K2001-☐ Fyrestan Tube can be separately ordered.

List Number**	Application	Wires	Insulators	Head	Protecting Tube	Length	Certification	Price	Add for L&N Report of Calibration
8710-K2002-☐-☐	For high precision, using an ice-bath reference junction.	24 AWG platinum, 10% rhodium-platinum, extending beyond head for use in ice-bath reference junction.	Std 722-B single-hole, Std 715-B fish-spine type, Std 10737 spacer (K2002 only) and glassfibre tubing on extensions.	PI-142-2, a PI-142 head modified to permit extension of thermocouple wires.	K2002 Fyrestan, 7/16″ ID, 11/16″ OD.	As specified. Standard lengths: 12, 18, 24, 30, 36, 42, 48 and 60 inches.	None. NBS Report of Calibration or Test can be obtained on request, at additional charge. For L & N Report of Calibration, specify 8710-B-K2002-☐-☐ or 8710-B-K2025-☐-☐.	-12 $82.00 -18 100.00 -24 117.00 -30 134.00 -36 151.00 -42 173.00 -48 190.00	$95.00
8710-K2025-☐-☐	Primarily for use with a CF-19 Equalizing Block in a 9003 Thermocouple Checking Furnace.				K2025 Fyrestan, ¼″ ID, ⅜″ OD.			-12 85.00 -18 103.00 -24 120.00 -30 137.00 -36 154.00 -42 176.00 -48 193.00	95.00
8700-☐	For measurements of moderate precision, using copper leadwires.	24 AWG platinum, 10% rhodium-platinum.	Std 722-B single-hole.	PI-143, with thermometer for reference junction temperature*** calibrated in degrees C (required for NBS calibration; can also be supplied calibrated in F).	K2002 Fyrestan, 7/16″ ID, 11/16″ OD.	As specified. Standard lengths: 12, 18, 24, 30, 36, 42, 48 and 60 inches.	None. NBS Report of Calibration or Test can be obtained on request, at additional charge. For L & N Report of Calibration specify 8700-B-☐.	-12 71.00 -18 91.00 -24 111.00 -30 130.00 -36 149.00 -42 173.00 -48 192.00	95.00
Std 780-B-☐	For high precision, using an ice-bath reference junction.	24 AWG platinum, 10% rhodium-platinum.	Std 722-B single-hole.	None	None. K2001 Fyrestan tube should be separately ordered.****	As specified. Standard lengths: 12, 18, 24, 30, 36, 42 and 48 inches.	None. NBS Report of Calibration or Test can be obtained on request, at additional charge. For L & N Report of Calibration, specify Std 784-☐ or Std 784-A-☐.	-12 50.75 -18 66.50 -24 83.00 -30 98.50 -36 114.00 -42 129.00 -48 143.00	N/A
Std 784-☐			Std 722-B, Std 715-B (fish-spine) and 1 Std 10737.			As specified. Standard lengths: 24, 30, 36, 42 and 48 inches.	L & N Report of Calibration included.	-24 165.50 -30 179.50 -36 192.00 -42 205.00 -48 217.00	Included
Std 784-A-☐			None			As specified. Standard lengths: 24, 30, 36, 42 and 48 inches.		-24 156.50 -30 169.00 -36 181.50 -42 194.00 -48 206.00	Included

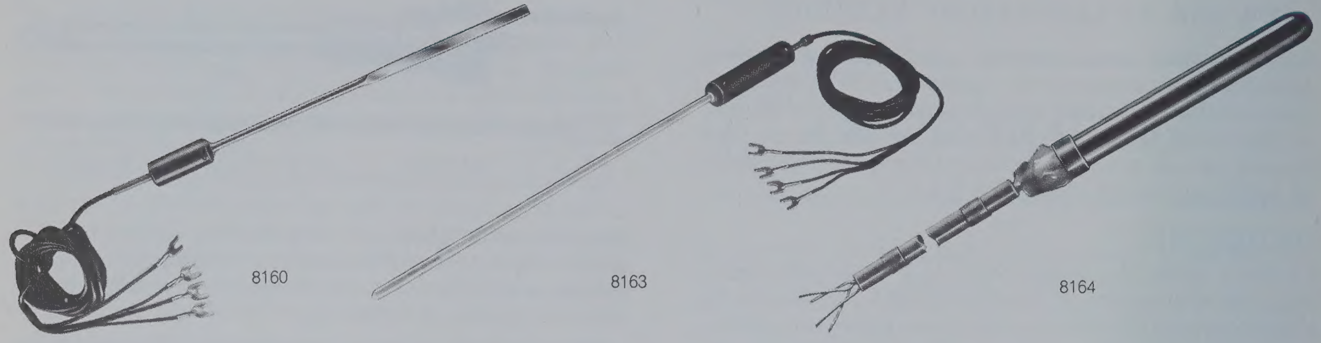
Base-metal thermocouples can be supplied for use as standards, tagged at additional charge to show their deviation from millivolt-temperature characteristics.

***First suffix is length of couple in inches. Second suffix, where applicable, is length of thermocouple wire extension required to reach ice-bath; add $2.00 per inch (includes both wires).*

****Approximate limit of error within which reference-junction temperature may be measured is ±2 degrees C.*

*****K2001-☐ Fyrestan Refractory Protecting Tube; 7/16″ ID, 11/16″ OD, with collar at open end. Price, $6.60 for 12″ tube; $2.90 for each additional 6″ increment.*

PLATINUM RESISTANCE THERMOMETERS



FOR PRECISION LABORATORY WORK

The 25-ohm 8163 Platinum Resistance Thermometer is designed in accordance with National Bureau of Standards Research Paper No. 508. Practically strain-free, it is intended for the most precise measurements. Any expansion or contraction is taken up in the spring-like coils. Any internal strains set up in drawing or winding are relieved by annealing. The result is an alpha value of 0.003925 or greater.

For measurements over a shorter temperature range and/or in confined areas, the 25-ohm 8160 is available. Strains are minimized by annealing the wire in a furnace before and after winding. The bifilar winding on a flat mica strip is sealed in dry air within a flat metal case.

For use with low-temperature calorimeters, the 8164 is only 6 cm long—so small it mounts entirely inside a calorimeter. The 8164 is also used for cryogenic calibration. To provide maximum stability, the platinum sensitive element is wound with minimum strain on a mica cross, and sealed in a helium-filled platinum tube. For information on the construction of the 8164, refer to Bureau of Standards Research Paper RP-1466.

The thermometers, tabulated below, are of the four-lead potential-terminal type. On special order, the 8160 or 8163 can be supplied as a four-lead loop-type for temperature-difference measurements.

Calibration data for the 8160 and 8163 can be supplied by L&N at additional cost; for the 8164, you must arrange with NBS for a Report of Calibration. (See page G-5). With calibration data, the combination of these resistance thermometers and the 8069 Type G-2 Mueller Bridge has an overall limit of error in the order of ±0.01 C. With a less precise bridge (e.g., the Type G-1 Mueller Bridge), the overall limit of error is in the order of ± (0.01 C + the limit of error of the bridge).

List No.	Description	Range	Leadwire	Time Constant	Report of Calibration*	Price
8160	Platinum wire element as described above. Resistance about 25.5 ohms at 0 C. Resistance change about 0.1 ohm per degree C. Element enclosed in a copper-nickel alloy tube, flattened to 2 mm thick and slightly over 1 cm wide over 14 cm of its length. Sensitive portion about 8 cm long.	−40 to +100 C	4-lead cable, 8′ long	11 Sec.	None	$480.00
8160-B					L&N: calibration at ice, steam and approx. 50 C.	655.00
8163**	Platinum wire element as described above. Resistance about 25.5 ohms at 0 C. Resistance change about 0.1 ohm per degree C. Element enclosed in Pyrex tube 7.35 mm in diameter, extending approximately 46 cm from head. Sensitive portion about 33 mm long.	−183 to +500 C (Thermal-free construction)		6 Sec.	None	575.00
8163-B-**					L&N: oxygen, triple point of water, tin and zinc points.	825.00
8163-C**					L&N: triple point of water, tin and zinc points.	750.00
8163-Q**	Same as 8163 above, except element is mounted in a quartz tube.	−183 to +650 C			None	675.00
8163-QB**					L&N: oxygen, triple point of water, tin and zinc points.	925.00
8163-QC**					L&N: triple point of water, tin and zinc points.	850.00
8164	Platinum wire element as described above. Resistance about 25.5 ohms at 0 C. Resistance change about 0.1 ohm per degree C. Element enclosed in platinum tube 5.7 mm OD, 6 cm over-all length. Sensitive portion about 39 mm long. Helium-filled.***	−261 to +250 C (For low-temperature calorimeters, thermal-free construction)	4 platinum leads, 3″ long	7 Sec.	None	461.00
8164-B					L&N: triple point of water, oxygen, steam and tin points for span of −183 to +250 C. (For other points, arrange with NBS for Report of Calibration.)	736.00

**Report of Calibration includes a resistance ratio vs. temperature table of one degree increments over the range indicated. An inverse difference tabulation facilitates interpolation to 0.0001 C.*

***For maximum protection during shipment and storage, a sheet aluminum box (gray enamel finish) with hinged lid and latches, containing foam polystyrene formed to hold the thermometer firmly in place is available. To obtain any 8163 or 8163-Q Series Resistance Thermometer shipped in an 039691 Protective Case add the suffix "-PK" to the list number (for example, 8163-B-PK, 8163-QB-PK, etc.) Price is that of resistance thermometer plus price of 039691 ($59.50).*

****Can be supplied filled with dry air (instead of helium) for use over the range of −183 to +500 C.*

CALIBRATION OF PRECISION PRIMARY ELEMENTS

CERTIFICATION OF PLATINUM, 10% RHODIUM-PLATINUM THERMOCOUPLES

The 8700, 8710-K2002, 8710-K2025, Std 780-B and 780-F purchased for use as primary standards, and having a minimum length of 24 inches, can be supplied with an NBS Report of Calibration or Test, at additional charge, upon request. Bare wires only are sent to the Bureau by L&N. Following the tests, the bare thermocouple element made from these wires is returned coiled on a spool with an NBS seal; this is then shipped to you with seal intact as received. The other components are shipped assembled when possible.

Since this procedure results in some delay, L&N has set up an L&N Report of Calibration as a customer service. This Report applies to the thermocouples listed above, and to the Std 784 and 784-A elements.

Thermocouples are made from selected annealed wire, samples of which have been calibrated at the freezing points of gold (1063.0 C), silver (960.5 C), antimony (630.5 C), and zinc (419.5 C) by the National Bureau of Standards. Because of the high accuracy of this type of calibration (±2 C at each fixed point) and also because of the uniformity in thermoelectric properties of the wire, the values are at least as accurate as if the thermocouple had been calibrated directly by comparison with a standard thermocouple. Using the report from National Bureau of Standards as a basis, L&N will supply a report giving the emf in absolute millivolts vs temperature in degrees C, in one-degree steps from 0 to 1450 C with the reference junction at 0 C. The minimum length of thermocouple to be supplied with a report is 24 inches, the maximum 120 inches.

CALIBRATION OF PRECISION PLATINUM THERMOMETERS

L&N REPORT—To calculate actual temperatures from measured resistance values, the calibration of precision platinum resistance thermometers provides the necessary constants for use in the Callendar formula or, if the thermometer is to be calibrated for use below 0 C, the modified Callendar formula. For details, send for the L&N Technical Publication A1.2101, "Calibration Techniques for Precision Platinum Resistance Thermometers".

To relieve you of the time-consuming use of the Callendar formula to obtain resistance-temperature values, L&N calibration data is supplied in tabular form in one-degree intervals. This is accomplished by determining the necessary resistance-thermometer constants and programming a computer for the applicable Callendar formula.

The first column of the table lists values of temperature; the second column provides Rt/Ro (ratio of resistance at the stated temperature to the resistance at the ice point); and the third column gives the reciprocal of the difference between each two successive values in the second column. These reciprocal first differences are included to facilitate interpolation. Error introduced by using linear interpolation is less than 0.0001 C.

NBS REPORT—A report of calibration can be obtained from the National Bureau of Standards for 8160, 8163, 8163-Q and 8164. The following schedules are available. Prices are subject to change without notice.

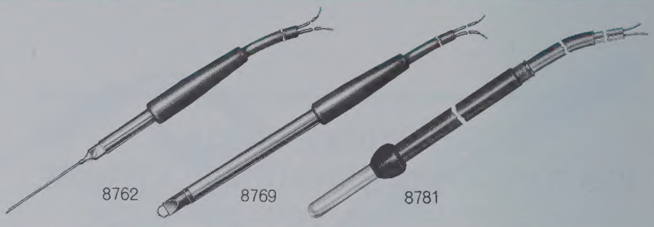
For L&N List No.	Item	Description	Fee*
8163-C & 8164	203.103a	Standard platinum resistance thermometers — calibration at the ice, steam and sulfur points. Table will be furnished with entries at 1-degree intervals.	$225.00
8163-B & 8164	203.103b	Standard platinum resistance thermometers — calibration under 203.103a and at the oxygen point. Table will be furnished with entries at 1-degree intervals	300.00
8160-B	203.103c	Calorimetric-type platinum resistance thermometers — calibration at the ice and steam points and at approximately 50° C. Table will be furnished with entries at 1-degree intervals	225.00
8164	203.103d	Capsule-type platinum resistance thermometers — comparison calibration over the range from 12° to 90° K. Results will be in the form of a table with entries at 0.1 degree intervals. Additional tables are not available unless requested at the time of test. See item 203.103f	590.00
—	203.103e	Determination of the average temperature coefficient of electrical resistance over the interval 0° to 100° C. Minimum length, 16 inches. Samples must have a resistance of at least 0.1 ohm per foot at the ice point	95.00
—	203.103f	Each additional table expressing the results of test under items 203.103 a, b, or c Additional tables under item 203.103d are not available unless requested at the time of test.	40.00
—	203.103g	Item 203.103f if requested at the same time as the test of the thermometer under items 203.103 a, b, c, or d	34.00
—	203.103h	Capsule-type platinum resistance thermometers — mounting this type of thermometer for test under item 203.103 a or b. Not applicable to items 203.103d	15.00

**Prices subject to change without notice.*

IRON-CONSTANTAN THERMOCOUPLES

FOR PHYSIOLOGICAL TEMPERATURE MEASUREMENTS

Special iron-constantan thermocouples are available for applications such as subcutaneous, skin-surface and rectal temperatures.



List Number	Typical Applications	Description	Limit of Error	Extension Wire	Price
8762	For subcutaneous temperatures	Iron and constantan thermocouple in 2-inch hypodermic needle, No. 19 Stubs' gauge (diameter, 0.042 inch).	±0.75 F between 90 and 110 F; ±1.0 F between 25 and 125 F.	10 feet of extension wire is connected to each thermocouple.	$81.00
8769	For skin-surface temperatures	Iron and constantan thermocouple in aluminum handle, with removable protecting cap.	±0.75 F between 90 and 110 F.		74.00
8781	For rectal temperatures	Iron and constantan thermocouple in watertight gold-filled tube about ¼″ OD, 1⅜″ long.			65.50

SELECTED THERMOCOUPLE WIRES

Standardized wires, bare and insulated, are available in a number of sizes. All are manufactured to rigid specifications to obtain desired chemical, physical and electrical properties. Sample sections are cut from each reel, made into thermocouples, and carefully tested for accuracy of calibration.

DUPLEX WIRES—SOLID CONDUCTORS—PREMIUM GRADE— Listed below are 20- and 24-gauge insulated thermocouple wires and 16-gauge extension wires for base-metal thermocouples. Correction data is not supplied with these stocked wires. Minimum order for any one type of 20- or 24-gauge wire is 200 feet; for any one type of 16-gauge wire, 500 feet. Each wire is checked against platinum so even individual wires from duplex cables can be intermixed and yield stated accuracy.

BARE WIRES—The wires listed below can be used to make platinum, rhodium-platinum thermocouples for use over the listed temperature ranges within stated limits of error.

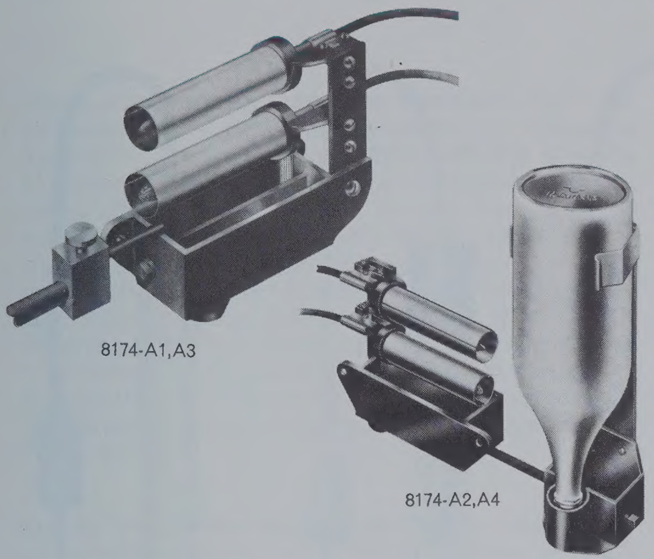
Wire	Limits of Error*		AWG	Wire Number	Price Per Inch
	Temperature Range	Error			
Platinum	0 to 1000 F 1000 to 2700 F	±2.5 F ±0.25%	24	24-1-6	$1.05
Platinum-10% Rhodium			24	24-1-7	1.05
Platinum-13% Rhodium			24	24-1-8	1.05

*When expressed as a percentage, the limit of error is a percentage of the temperature reading, not of the range.

Wire	Limits of Error*		Insulation		AWG	Dimensions (Inches ± 1/64)	Wire Number	Price Per Foot
	Temperature Range	Error	On Each Wire	Overall				
Iron and Constantan (Type J)	−310 to −100 F −100 to +600 F 600 to 800 F 800 to 1400 F	±2% ±2 F ±⅓ % ±⅓ %	Silicone-Impregnated Asbestos	Glass Braid, Silicone Impregnated	20 24	0.065 x 0.095 0.055 x 0.070	20-50-4-A 24-50-4-A	$0.12 0.10
			Extruded Nylon	Extruded Nylon	24	0.050 x 0.085	24-50-24-A	0.09
			Enamel, Asbestos, Silicone-Resin Impregnated	Asbestos Braid, Silicone-Resin Impregnated	16	0.205 x 0.300	16-51-2-A	0.22
			Polyvinyl Plastic	Nylon	16	0.105 x 0.185	16-51-16-A	0.14
Copper and Constantan ('38) (Type T)	−300 to −75 F −150 to −75 F −75 to +200 F 200 to 700 F	±1% ±1% ±¾ F ±⅜%	Enamel; Double-Glass Wrap; Moisture and Heat-Resistant Compound	Glass Braid; Moisture and Heat-Resistant Compound	20 24	0.060 x 0.095 0.050 x 0.070	20-55-1-A 24-55-1-A	0.14 0.10
			Extruded Nylon	Extruded Nylon	24	0.100 diam.	24-55-15-A	0.10
			Enamel, Asbestos, Silicone-Resin Impregnated	Asbestos Braid, Silicone-Resin Impregnated	16	0.205 x 0.280	16-56-2-A	0.24
			Polyvinyl Plastic	Polyvinyl Plastic	16	0.165 x 0.256	16-56-18-A	0.15
Chromel and Alumel (Type K)	32 to 530 F 530 to 2300 F	±2 F ±⅜%	Silicone-Impregnated Asbestos	Glass Braid, Silicone Impregnated	20	0.065 x 0.095	20-58-1-A	0.17
			Double-Glass Wrap, Silicone-Resin Impregnated	Glass Braid, Silicone Impregnated	20	0.055 x 0.090	20-58-8-A	0.17

* When expressed as a percentage, the limit of error is a percentage of the temperature reading, not of the range.

8174-A☐ WET- AND DRY-BULB ASSEMBLY



FOR RELATIVE-HUMIDITY MEASUREMENTS IN DUCT INSTALLATIONS

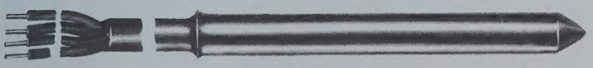
To measure relative humidity or temperature in ducts, flues, etc. as a basis for regulating air-conditioning systems, four Wet-and-Dry-Bulb Assemblies are available. The 8174-A1 and -A2 measure temperatures between 32 F at the wet bulb and 150 F at the dry bulb. The 8174-A3 and -A4 assemblies measure relative humidity between 32 F (wet bulb) and 175 F (dry bulb). Similarly constructed, each assembly is equipped with two nickel Thermohm elements, bracket-mounted in cylindrical shields over a water trough. A wick dips into the trough to keep a water-saturated layer on the wet bulb. In the 8174-A1 and -A3, a feed valve is used to feed the trough; in the 8174-A2 and -A4, a bottle feeder is supplied.

Application	Mounting Device	Thermohm Detector*	Water Feed Device	Assembly List No.	Price
Wet- and dry-bulb temperatures: 32 to 150 F	Includes Thermohm brackets, wet-bulb radiation shield and water feed trough. For replacement wicks, specify quantity of Std 1006-2.	Includes two 8180-3 Thermohm detectors, nickel - wire resistor, 100 ohms at 68 F; 3-ft rubber-covered attached leadwire.	Feed Valve: supplied loose for connection to water - line tapped by user's needle valve.	8174-A1	$184.00
			Bottle Feeder: does not include connecting tubing.	8174-A2	243.00
Relative humidity over range of 32 to 175 F	Includes Thermohm brackets, wet- and dry-bulb radiation shields, and water feed trough. For replacement wicks specify quantity of Std 1006-4.	Includes one 8182 pair of matched Thermohm detectors; nickel-wire resistor, 50 ohms at 68 F; 10-ft lead-covered attached leadwire, sealed against entrance of moisture.	Feed Valve: supplied loose for connection to water - line tapped by user's needle valve.	8174-A3**	356.00
			Bottle Feeder: does not include connecting tubing.	8174-A4**	401.00

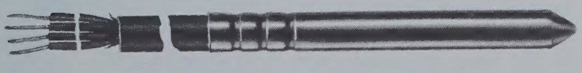
**Thermohm detectors are matched to 0.5 F; individual detectors are accurate to ±0.5 F.*

***For use with 69151 Speedomax G Model S Relative Humidity Recorder. For added protection against corrosion, the wet-bulb Thermohm detector can be supplied on special order with a gold-plated case instead of brass.*

8193-☐ SERIES THERMOHMS



8193-3, 8197-10



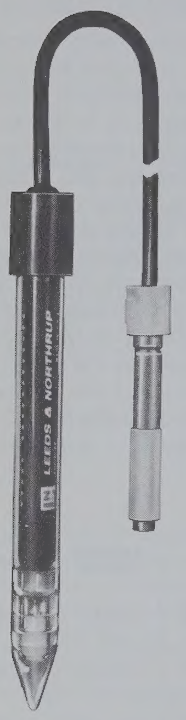
8194-3

FOR TEMPERATURE DIFFERENCE

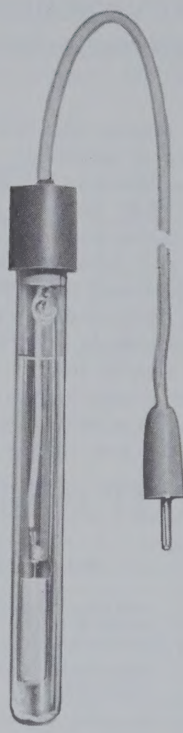
Detectors for temperature difference are listed and priced as single Thermohm elements; to obtain a pair (matched to 0.1 F), order two of the desired type; to obtain two individually matched pairs, order four of the desired type. When it is necessary to replace or repair one detector of a matched pair, the other should be returned to L&N for matching.

Application	Range	Type	Limit of Error	List Number	Attached Leadwire	Price
Temperature Difference	32 to 150 F	Copper, 10 Ohms	±0.5 F. Pairs are matched to 0.1 F	8194-3	Four-conductor, neoprene-covered, 3-ft. long.	$64.00
	32 to 250 F	Copper, 10 Ohms		8193-3	Four-conductor, lead-covered, 3-ft. long.	50.00
		Copper, 100 Ohms		8197-10	Four-conductor, lead-covered, 10-ft. long.	82.00

pH ELECTRODES – GLASS, REFERENCE & METAL



117169



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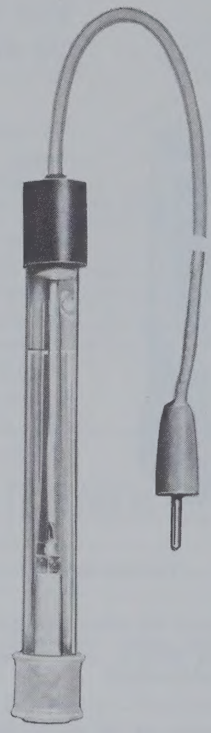

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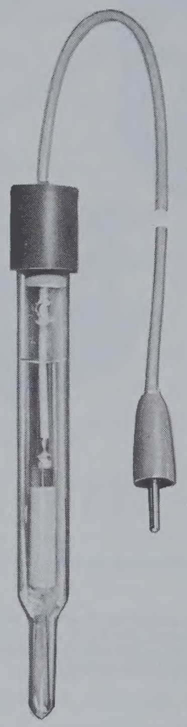
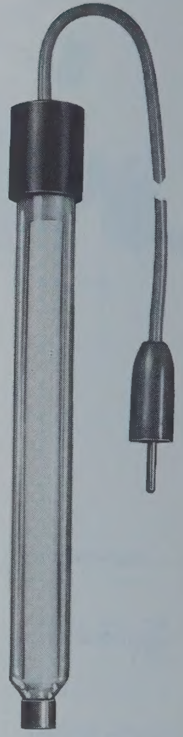


STD 1199-13



117225

GLASS ELECTRODES

117169 GLASS ELECTRODE—General-purpose—internally shielded—shock-resistant—low sodium-ion error—high temperature service. pH range, 0 to 14 pH. Temperature range, 10 to 100 C. Isopotential value, 0 mV at 7 pH. Internal element is packed calomel. Diam. of cap, ⅝″; of stem, ½″. Length: electrode, 5″; shielded leadwire, 30″. Price—$26.00.

117235 GLASS ELECTRODE—*Same as 117169 above, except:* Internal element, packed silver/silver chloride, for conditions not permitting use of mercury. Price—$26.00.

117224 GLASS ELECTRODE—For low-temperature service. *Same as 117169 above, except:* pH range, 0 to 11.0 pH; temperature range, −5 to +20 C. Price—$26.00.

REFERENCE ELECTRODES

117208 REFERENCE ELECTRODE—General-purpose—L&N dual-glass junction. Temperature range, −5 to +90 C; may be used intermittently to 100 C. Internal element, packed calomel; electrolyte, saturated potassium chloride. Diameter of cap, ⅝″; of stem, ½″. Electrode length, 5″; leadwire (pin terminal), 30″. Price—$19.00.

117236 REFERENCE ELECTRODE—*Same as 117208 above, except:* Internal element, packed silver/silver chloride. Price—$19.00.

117228 REFERENCE ELECTRODE—For unusual or severe service, including non-aqueous conditions. *Same as 117208 above, except:* Liquid junction consists of ground-glass sleeve covering small hole in glass stem; temperature range is −5 to +90 C. Price—$20.50.

STD 1199-13 REFERENCE ELECTRODE—General-purpose—fiber junction, otherwise same as 117208 above. Price—$22.00.

METAL ELECTRODES

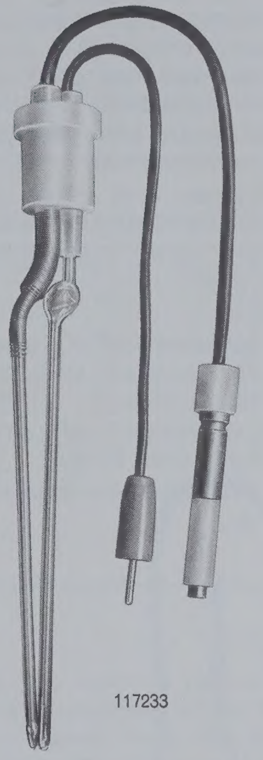
117225 PLATINUM ELECTRODE—For redox measurements (with 117208, 117228, or Std 1199-13 reference electrode) or Karl Fischer titrations (two 117225 electrodes required). Sensing element is durable platinum band on glass, ¼″ diameter, ⅜″ length, 0.3 sq. in. surface area, extending below glass stem. Diameter of cap, ⅝″; of stem, ½″. Electrode length, 5″; leadwire (with pin-type terminal) is 30″ long. (For connection to L&N 7400-A2 Series pH Meters, a 128335 Jumper must be ordered separately.) Price—$42.00.

117226 SILVER ELECTRODE—*Same as 117225 above, except:* Sensing element is billet-shaped, ¼″ in diameter, extending 7/32″ below glass stem; electrode length, 5″. A 128335 Jumper to convert pin-type terminal of leadwire to 7400-A2 Series pH Meters must be ordered separately. Price—$31.00.

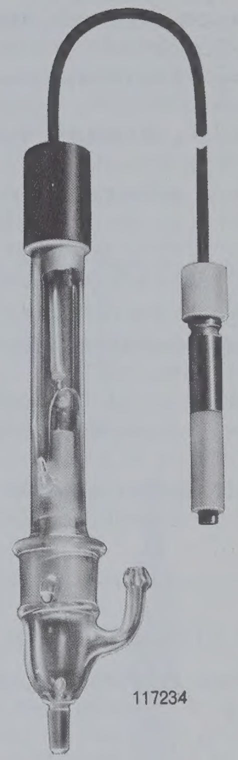
pH ELECTRODES–SPECIALIZED

117233 MINIATURE pH ELECTRODE ASSEMBLY—Offers the convenience of a combination assembly for measuring samples as small as a single drop, with the economy of separately replaceable glass- and reference-electrode stems. Range, 1 to 11.5 pH. Temperature range, 15 to 40 C. Internal elements, silver chloride. Liquid junction (reference electrode), dual-glass type. Electrolyte (reference electrode), 2-normal potassium chloride, saturated with silver chloride. Diameter of cap: ¾″ (fits 7677 Electrode Holder); of stems, each ⅛″. Electrode lengths, 6″. Insertion: fits apertures as small as 7 mm in diameter, to a depth of 4″. Lead lengths, 30″; glass-electrode lead is shielded, reference-electrode lead has pin-type terminal. Price—$47.00.

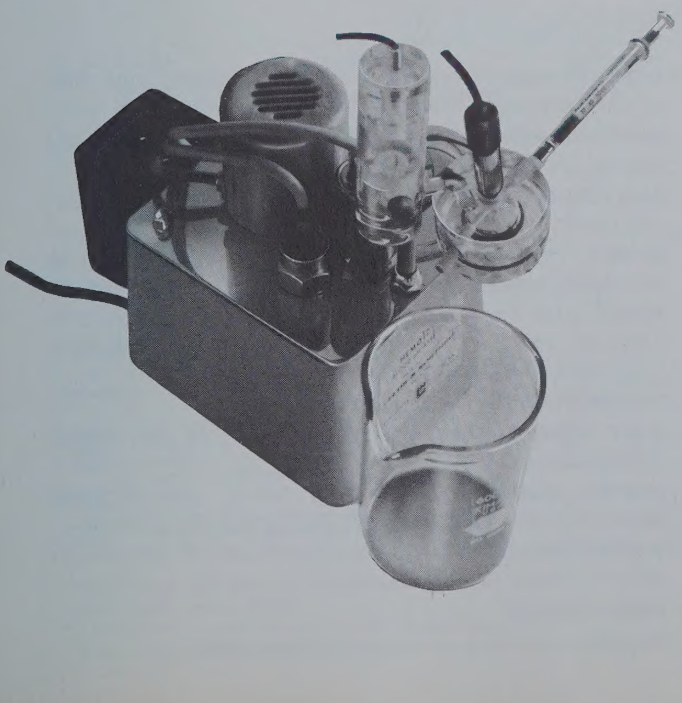
117234 HYPODERMIC GLASS ELECTRODE—Designed for anaerobic measurements of small samples, including body fluids. A sample of 0.6 ml is drawn by hypodermic needle into a small chamber surrounding a pH-sensitive membrane. After the needle is removed, the sample chamber with electrode intact is immersed in a beaker containing saturated potassium chloride. A 117208 or 117228 Reference Electrode (purchased separately) is then immersed in the potassium-chloride solution to complete the circuit. Shielded leadwire length, 30″. Price—$58.00.



117233



117234



HEMOTRON BLOOD pH ASSEMBLY

Offering unusual simplicity and convenience in anaerobic measurement of pH in micro-quantities of blood, the compact L&N HEMOTRON Electrode assembly features a short, tubular sample cavity, centrally positioned in a thermostated transparent block. The cavity incorporates a removable, miniature glass electrode and a junction of flowing reference electrolyte. The latter provides a more stable residual-junction potential than static diffusion types. Although the HEMOTRON Electrode will operate satisfactorily with any pH meter of suitable sensitivity, the new L&N 7407 Expanded-Scale pH Meter is especially useful for this service. It is described on page K-2. Another L&N Meter suitable for blood pH measurements—but with less readability than the 7407—is the 7405 Expanded-Scale pH Meter, also described on page K-2.

7707-A1 HEMOTRON ELECTRODE without meter. Price—$695.00.

7407-A7 ASSEMBLY including HEMOTRON and 7407 pH Meter. Price—$1160.00.

7405-A7 ASSEMBLY including HEMOTRON and 7405 pH Meter. Price—$1085.00.

pH ELECTRODE ACCESSORIES

CHEMICALS

103-1-0-1 REFERENCE BUFFER SOLUTION — 4.01 ±0.01 pH at 25 C. One pint, in polyethylene bottle, $3.40.

103-1-0-2 REFERENCE BUFFER SOLUTION—6.86 ±0.01 pH at 25 C. One pint, in polyethylene bottle, $3.40.

103-1-0-3 REFERENCE BUFFER SOLUTION—9.18 ±0.01 pH at 25 C. One pint, in polyethylene bottle, $3.40.

103036 REFERENCE BUFFER SOLUTION—7.386 ±0.003 pH (within ±0.003 pH of NBS primary-standard buffer solution) at 37 C. 500 ml in non-solvent glass bottle, $6.80.

STD 1262-1 KCl CRYSTALS (4 oz), $1.90.

STD 1083 KCl CRYSTALS (1 lb), $2.95.

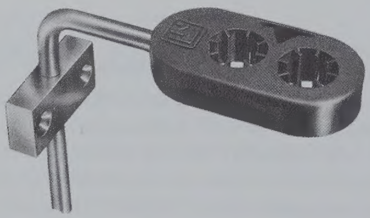
103025 REFERENCE ELECTRODE SOLUTION—2N KCl, saturated with AgCl, for 117233 Miniature pH Electrode Assembly. 2 oz in polyethylene bottle, $2.25.

103026 MEASURING ELECTRODE SOLUTION—7 pH buffer containing KCl. 2 oz in polyethylene bottle, $2.25.

103031 2N KCl SOLUTION 16-oz. bottle; for silver-chloride reference electrodes, $4.65.

ELECTRODE HOLDERS

145044 ELECTRODE HOLDER—Consists of metal rod, 6″ long, ¼″ diameter, with molded plastic electrode holder having two holes for electrodes with stem diameter of ½″. A small slotted V-shaped hole accommodates either a mercury thermometer or a 145027 Temperature Compensator Clip. Rod can be attached by laboratory clamp (not included) to a laboratory support stand; $4.40.

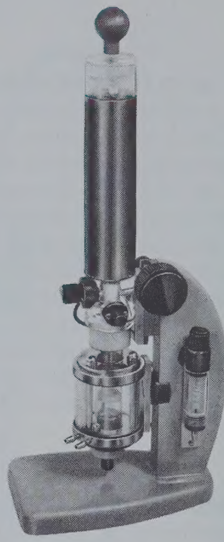


145045 ELECTRODE HOLDER—*Same as 145044, except:* metal rod has 90° bend; $7.70.

7677 ELECTRODE HOLDER—*Same as 145044, except:* molded plastic electrode holder has one hole enlarged to accommodate ¾″ diameter cap of 117233 Miniature pH Electrode Assembly; $4.00.

128335 JUMPER—Shorts glass-electrode input to one Karl Fischer input jack, for measurements with Metal Electrodes. Lead length (not including terminals), 4″; $4.40.

7736 POLAROTRON*



For ultimate accuracy and convenience in polarographic analysis, the Polarotron P-40 dropping-mercury electrode eliminates the problems encountered in the setup, operation and maintenance of ordinary polarizing cells.

The combination of the Polarotron P-40 and the L&N Electro-Chemograph® provides scientists and quality control technicians with a rapid, simple, economical and accurate means of analysis with recording display.

The Polarotron electrode assembly combines the dropping-mercury system, test vessel, reference electrode, electrolytic bridge, water bath, gas flowmeter and constant-head mercury column in a rugged, compact unit.

In operation, the instrument is connected to the Electro-Chemograph and a constant-temperature water supply. Sample is placed in the test cell, purged and analyzed.

SPECIFICATIONS

MERCURY HEAD—Constant level, automatically controlled by capillary valve. Mercury requirement only 50 ml.

DROPPING-MERCURY ELECTRODE—Pretested, 2-6 sec, 1-3 mg/sec. Screw bushing for easy installation.

REFERENCE ELECTRODE—Permanent-type saturated calomel electrode, non-polarizing, portable.

BRIDGE—Permanent microporous ceramic. Less than 50 ohms (KCl solution), approx. 0.5 microliters/min. diffusion.

PURGE GAS—Flow meter and regulator, 0-1.4 std. cfh. Two-way valve for purging and blanketing. Separate purge-gas ring fitted with spring plunger.

THERMOSTATING—Glass-jacketed assembly.

D.M.E. ASSEMBLY (TUBE)—Laterally movable with helical microscope drive.

SAMPLE CHANGE—Achieved by tilting glass-jacketed assembly; operation requires only a few seconds.

DIMENSIONS—20″ max, 17″ min (h) x 6″ (w) x 8″ (d); weight approx. 8 lb.

PRICE—$529.00

**Registered trademark of Ladisch Analytical Instruments.*

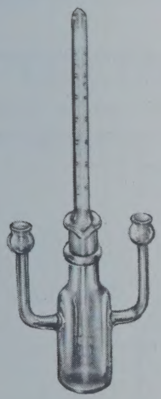
CONDUCTIVITY CELLS

A selection of cells for measuring electrolytic conductivity includes cells for general laboratory use and Jones Conductivity Cells for high-precision measurements. These Jones Conductivity Cells are designed for extremely precise conductivity determinations and may be used for measurements usually kept within 1,000 to 10,000 ohms measured resistance. In addition, dip-type cells for use with portable indicators are listed.

Since electrolytic solutions have coefficients of about 2% per degree C, the solution temperature must be controlled to within 0.001 C to avoid errors (from temperature variation) in excess of 0.002%. To assure this precision, we recommend the use of the 8401 Bath Assembly (see chapter on Standards). The Jones bridge and platinum resistance thermometer can be used to measure its temperature.

CONDUCTIVITY CELLS FOR GENERAL LABORATORY USE

List Number	Application	Cell Constant, Reciprocal cm	Volume, cc	Electrode Area, cm²	Platinum Weight, gm	Price
4911	For low-conductivity solutions	0.17	30	6.4	5.0	$245.00
4914	For medium-conductivity solutions	1.3	35	2.0	2.2	207.00
4915	For high-conductivity solutions	15.0	17	1.3	2.2	260.00
4912	For most solutions encountered in educational work	Adjustable from 4 to 18 (approx.)	—	1.4	1.3	P.O.R.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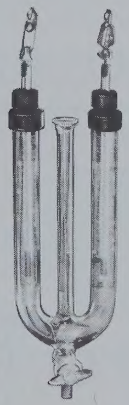
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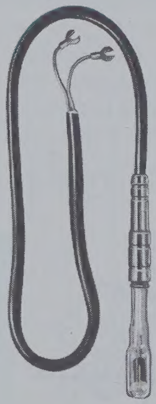
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4805-X1

DIP-TYPE CELLS FOR PORTABLE INDICATORS

List Number	Application	Cell Constant	Electrodes	Electrode Area	Cell Case	Price
4917	Medium or high conductivity solutions	0.8 cm^{-1}	Platinum	1.2 sq cm per electrode	Glass	$65.00
4920	Low conductivity solutions	0.1 cm^{-1}	Platinum	3.1 sq cm per electrode	Glass	75.00
4805-☐	General Purpose	0.01 to 50 cm^{-1}*	Platinum	2.6 sq cm per electrode	Halogenated polymer; with 6-ft length of 2-conductor rubber-covered leadwire.	80.00

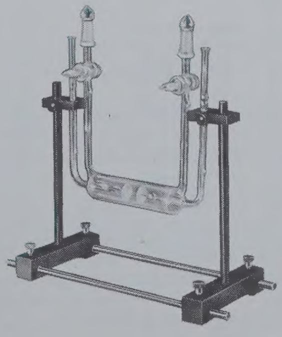
**For cell constants 0.01, 0.1, 1, 10, 25 or 50 add suffix: X01, X1, 1, 10, 25 or 50.*

JONES CONDUCTIVITY CELLS FOR HIGH PRECISION

List Number	Application	Cell Constant, reciprocal cm**	Volume, cc	Price
4942* 4943* 4944*	For conductivity water (conductance 1 x 10^{-8}) and poorly conducting solutions. Made of Pyrex glass. Unplatinized	0.05 0.25 1.00	65 65 65	P.O.R.
4945* 4946* 4947*	For high-conductivity solutions. Made of Jena glass. Unplatinized	5.00 25.00 150.00	30 30 30	P.O.R.

**For a Stand and Clamps to support any of these cells, specify 4990; price, $66.00.*

***Approximate; actual constant must be determined by measurement with a standard solution.*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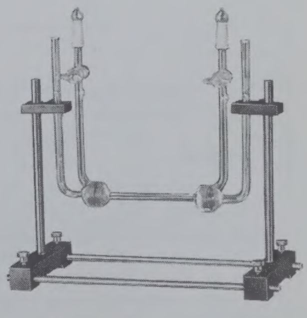
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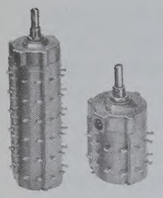
KEYS AND SWITCHES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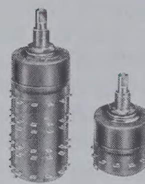
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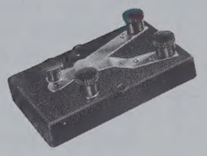
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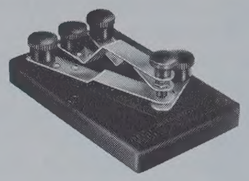
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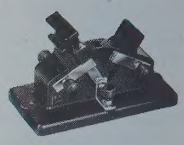

3294

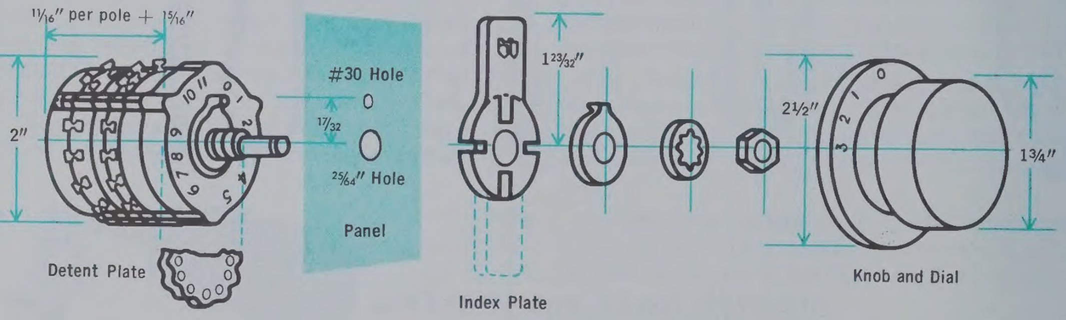
For a wide variety of laboratory and industrial applications where switch design requires low and stable contact resistance and low thermals, L&N offers the Type 31 Rotary Switch. Available in a number of switching combinations, from single-pole, 12- or 16-position to six-pole, 12- or 16-position, this switch is durable and reliable, and provides both convenience and smooth operation.

The Type 31 Switch can be supplied in a cast-aluminum housing for permanent mounting or bench-top use, to connect a number of individual primary elements to a single-point indicator or recorder. The 8248 Selector Switch is designed for two-lead thermocouples or electrolytic conductivity cells and the 8249 is used for three-lead Thermohm resistance-thermometer applications.

Also available is the totally-new 01-Series Silver Rotary Selector Switch, which provides low and stable contact resistance, exceptionally low-thermal emf and long life at temperature extremes, at a low price. Type 01-☐-☐-☐ Switches are designated as shown in the table below by indicating the number of decks (Block I), clockwise stop position (Block II), and the position of the flat on the shaft (Block III).

Two tapping keys are listed, one to facilitate the operation of galvanometers, the other designed primarily for use in a Wheatstone-bridge circuit. A pinch-type switch provides practically thermal-free galvanometer reversing.

ROTARY SWITCHES—Type 31 Series



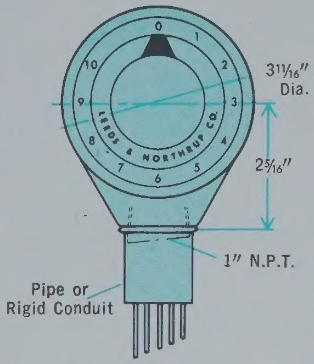
Type	Wafer Material	Switch Shaft	Poles	Switch Only		Switch Assembly*	
				List Number	Price***	List Number	Price***
12-Position	Molded alkyd	Linen-base phenolic	1	31-3-0-1	$18.50	8256-1-☐	$22.60
			2	31-3-0-2	26.50	8256-2-☐	30.60
			3	31-3-0-3	35.50	8256-3-☐	38.60
			4	31-3-0-4	44.50	8256-4-☐	46.60
			5	31-3-0-5	53.50	8256-5-☐	54.60
			6	31-3-0-6	62.50	8256-6-☐	62.60
	Lexan	Molded acrylonitrile-styrene copolymer**	1	031261	28.00	8256-1A-☐	31.10
			2	031262	39.00	8256-2A-☐	41.10
			3	031263	50.00	8256-3A-☐	51.10
			4	031264	61.00	8256-4A-☐	61.10
			5	031265	72.00	8256-5A-☐	71.10
			6	031266	83.00	8256-6A-☐	81.10
16-Position	Molded alkyd	Molded acrylonitrile-styrene copolymer**	1	031142	33.00	8257-1-1	36.10
			2	031272	44.00	8257-2-1	46.10
			3	031273	55.00	8257-3-1	56.10
			4	031274	66.00	8257-4-1	66.10
			5	031275	77.00	8257-5-1	76.10
			6	031276	88.00	8257-6-1	86.10

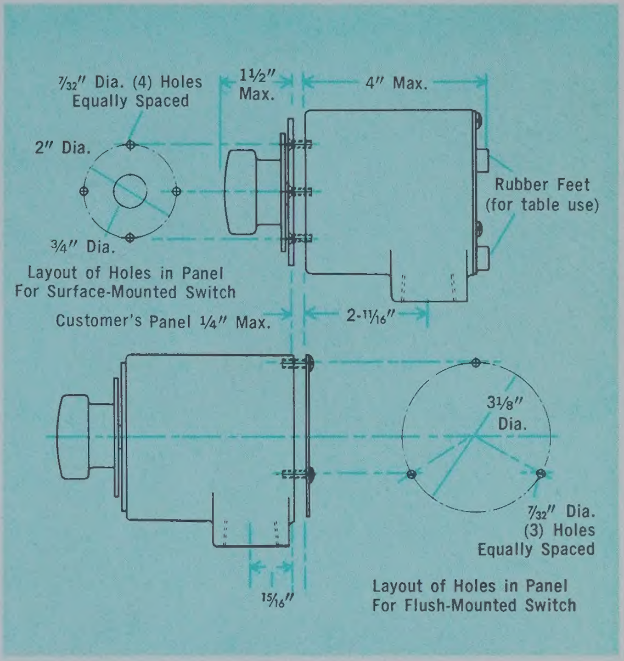
*Switch assembly includes switch, knob, dial and index. Final suffix number indicates type of knob-and-dial marking, and must be included where optional: "1" for blank dial, with optional top or bottom indexing; "2" for dial numbered 0-10, bottom reading, clockwise rotation; or "3" for dial numbered 0-10, top reading, clockwise rotation. Dial markings for "2" and "3" are approximately 3/16" high, 30° apart, with one 60° space between 10 and 0.

**Switches having an acrylonitrile shaft are of higher quality than those having a phenolic shaft, and are similar in design to those used in the 4393 Universal Ratio Set, the 4394 Ratio Set and the Type K Potentiometers.

***Subject to quantity discounts when purchased in lots of ten or more.

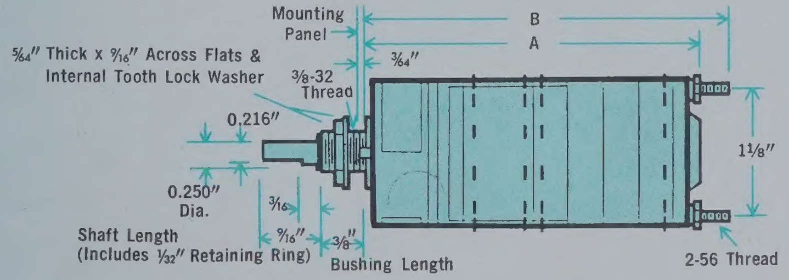
ROTARY SELECTOR SWITCHES FOR THERMOCOUPLES AND THERMOHM DETECTORS


3 11/16″ Dia.
2 5/16″
1″ N.P.T.
Pipe or Rigid Conduit
LEEDS & NORTHRUP CO.


7/32″ Dia. (4) Holes Equally Spaced
1½″ Max.
4″ Max.
2″ Dia.
Rubber Feet (for table use)
¾″ Dia.
Layout of Holes in Panel For Surface-Mounted Switch
Customer's Panel ¼″ Max.
2-11/16″
3⅛″ Dia.
7/32″ Dia. (3) Holes Equally Spaced
15/16″
Layout of Holes in Panel For Flush-Mounted Switch

Application	List Number	Number of Points	Scale Markings	Terminal Boards Supplied	Price
For thermocouples or electrolytic conductivity cells	8248-10	10 + Transfer	0 to 10	3	$65.00
	8248-12	12	1 to 12	3	68.00
	8248-16	16	1 to 16	4	75.00
For Thermohm resistance thermometers	8249-10	10 + Transfer	0 to 10	4	75.00
	8249-12	12	1 to 12	5	78.00
	8249-16	16	1 to 16	6	85.00

ROTARY SWITCHES—Type 01 Series


Mounting Panel
B
A
5/64″ Thick x 9/16″ Across Flats & Internal Tooth Lock Washer
3/64″
⅜-32 Thread
0.216″
1⅛″
0.250″ Dia.
3/16
Shaft Length (Includes 1/32″ Retaining Ring)
9/16″
⅜″
Bushing Length
2-56 Thread

DIMENSIONS

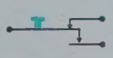
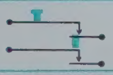
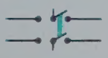
No. of Poles	Maximum Depth Behind Panel (inches)	
	A	B
1	1.503	1.605
2	1.821	1.917
3	2.139	2.230
4	2.457	2.542
5	2.775	2.917
6	3.093	3.230

Switch No. 01 - ☐ - ☐ - ☐ (I, II, III)

BLOCK I			BLOCK II				BLOCK III	
Number of Decks	Block No.	Price*	Clockwise Stop Position**	Block No.	Clockwise Stop Position**	Block No.	Shaft Construction*** (Flat on Shaft opposite:)	Block No.
1	01	$ 9.75	Continuous	00	7	07	Position 1	01
2	02	13.50	2	02	8	08	3	03
3	03	17.00	3	03	9	09	5	05
4	04	20.00	4	04	10	10	7	07
5	05	23.00	5	05	11	11	9	09
6	06	27.00	6	06	12	12	11	11

**Quantity discounts available on orders of 10 or more.* ****Round or slotted shafts available on special order.*
***Stops may be easily and quickly relocated in field.*

KEYS AND PINCH-TYPE SWITCH

List Number	Type		Characteristics	Price*
3702	Tapping Key		Single-contact and short-circuit key, used with galvanometers. When key is depressed, galvanometer deflects; so arranged that, when released, a damping resistance (not included) may be connected across galvanometer, assuring quick return to zero. Tungsten contacts; brass spring; bakelite base, with holes for mounting. 3″ x 4⅞″ x 1½″ (overall height).	$15.00
3701	Tapping Key		Double-contact key, used for closing two circuits with one movement. Similar to 3702, but provides two circuits, insulated from each other, operated by same motion. Top circuit closed before bottom circuit. When used with Wheatstone bridge, battery circuit is closed first, then galvanometer circuit. 3″ x 4⅞″ x 2″ (overall height).	20.00
3294	Pinch-Type Switch		For use as a practically thermal-free galvanometer-reversing switch and for general use in measuring circuits. Blades move through only 60°, held in open position by clicking device. Connections may be made within base to form a reversing switch. Has beryllium-copper blades, solid copper jaws, copper circuit through binding posts. Phenolic base has holes for mounting. 2½″ x 5″ x 3¼″ (overall height).	9.50

**Subject to quantity discounts.*

H

READOUT EQUIPMENT

Introduction H-1
Analog H-2
Digital H-7

20 21 22 23 24 25 26 27 28 29 30
CENTER CLIP
UNDER DARK AREA
2 3 5 6 7 8 9 10 11
FLEXELECT

READOUT EQUIPMENT: ANALOG & DIGITAL

To provide continuous measurement of dynamic signals (which vary with time), to conserve valuable laboratory man-hours by eliminating the tedious manual plotting of technical data, and to prepare a record which is valuable for later interpretation, Leeds & Northrup offers a variety of widely used null-balancing electronic Speedomax recorders for accurate, versatile, and reliable recording of analog information. L&N can supply recorders for measurements of temperature (with thermocouples, resistance thermometers or heat-radiation detectors), pressure, flow, pH, electrolytic conductivity, displacement, force, radiation, voltage, current, resistance, ratio, gas analysis, and many other quantities. This chapter lists representative models which are most applicable to laboratory use.

In addition, the chapter describes equipment which is available for the digital readout, through typewriter or tape punch, of certain high-precision L&N measuring instruments.

ANALOG RECORDING INSTRUMENTS

FACTORS IN SELECTION

Curve-plotting recorders are utilized when trend data and a permanent record of change with time are desired in analog form. Leeds & Northrup manufactures an extensive line of null-balance recorders—instruments which draw or print an analog record of the quantity being measured on a calibrated chart.

Among the benefits of recording are graphical indication of variables, convenient storage and presentation of data, observation of high-speed variations, and unattended operation.

Continuous records with one or more pens, or intermittent records with multiple-point printing, are available; recorders can be provided for a variety of types of curve drawing, including cartesian (strip chart), polar (round chart), X vs Time and X vs Y.

A recorder may measure directly from a primary element and read out in absolute units, or it can be used as a difference instrument (i.e. center "O"). Many L&N millivolt recorders are capable of both.

The function of a recorder may be simply to indicate changing data on a graph, or to act as a servo for control or transmission functions.

Other factors to be considered in selecting a recorder for a specific application include range, input impedance, speed of response, and the availability of special accessories or features which may be desired.

Because of the great variety of choices of L&N recorders which are available, we suggest you contact your local L&N sales engineer for detailed assistance regarding your specific application. A representative selection of Speedomax recorders for typical laboratory applications is presented in this chapter. The table below presents a quick reference *only to those recorders listed* in this publication.

CHARACTERISTICS AND FEATURES

TYPE—Employs a solid state or electronic amplification of unbalance and a reversing motor to effect balancing action.

MEASURING CIRCUIT—Automatically-balanced potentiometer when used with millivolt or volt sources; Wheatstone bridge when used with resistance elements. Reliable null-balance principle combines potentiometer or Wheatstone-bridge accuracy and stability with electronic sensitivity, providing reliable, reproducible recording.

MEASURING-CIRCUIT CURRENT—Supplied by line power, rectified and regulated by Zener-diode circuit.

REFERENCE - JUNCTION COMPENSATION — Automatic in thermocouple instruments.

QUICK RANGE CHANGE—Requires only plug-in card, a new scale and chart.

INSTALLATION EASE—Simply connect leadwires from power supply and detecting device and turn on power switch.

EXTERNAL TERMINAL BOARD (H & W)—All wiring connections are made at the back of the case. A cover plate and rubber grommets in knockouts protect the terminals.

	Characteristics	Speedomax Type H	Speedomax Type W	Speedomax Type W/L	Speedomax Type G
Dimensions	Size of Recorder Case	12″ high 11″ wide 13″ deep	12″ high 15″ wide 13″ deep	12″ high 15″ wide 13″ deep	20″ high 18¼″ wide 12⅝″ deep
	Calibrated Width of Scale and Strip Chart	6½″	9⅞″	9⅞″	9⅞″
	Length of Strip Chart in View	7½″	7½″	7½″	10″
General Purpose	Standard Millivolt	✓	✓		
	AZAR* (Compact, Portable)	✓	✓		
	AZAR* (Calibrated)	✓	✓		
Monitoring	2-Pen			✓	
	Multi-point (with Cleertrend)	✓	✓		
Precision Thermometry	Precision Resistance Thermometer				✓

**Adjustable-Zero, Adjustable-Range.*

OPTIONAL FEATURES

SELECTION OF RANGES—A wide selection of thermocouple, millivolt and other ranges is available.

SHORT SPANS—Down to 300 microvolts (H or W); voltage divider for high spans.

CHART SPEEDS—From 1 inch per hour to 4 inches per second (G); to 1 inch per second (H & W).

DUAL CHART SPEEDS—Manually or electrically selected.

MULTIPLE CHART-SPEED CHANGER—Provides 10 fixed chart speeds from 1 to 120 inches per hour.

FAIL-SAFE DEVICES—For amplifier and/or input failure.

OFF-SCALE LIMIT DEVICE—Provides reduced torque from balancing motor (and chart shut-off) at low and high ends of scale.

HIGH-IMPEDANCE AMPLIFIERS (G)—For source impedances up to 1 megohm.

CHART-MOTOR SWITCH—Toggle-type on-off switch inside case.

AIR-PURGE CONNECTION

EVENT PENS—Electrically-operated pens which mark in margin of chart.

PEN LIFTERS—Manually or electrically operated to lift recording pen and/or event pen off chart.

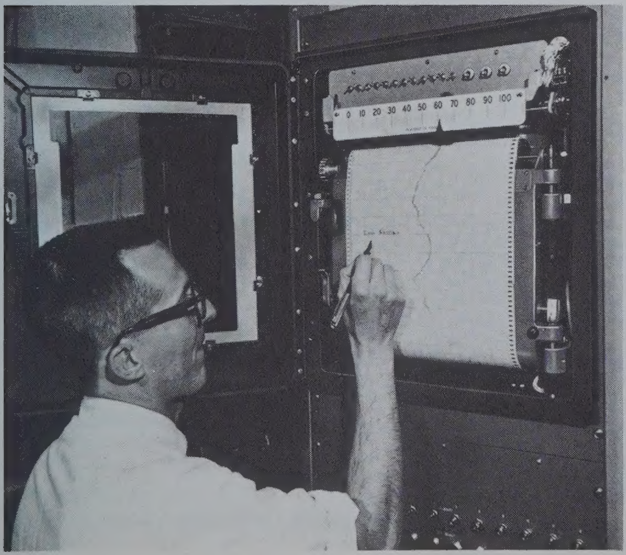
MULTI-POINT SELECTOR SWITCHES—Flexelect® pushbutton selection.

PORTABILITY OPTIONS (H & W)

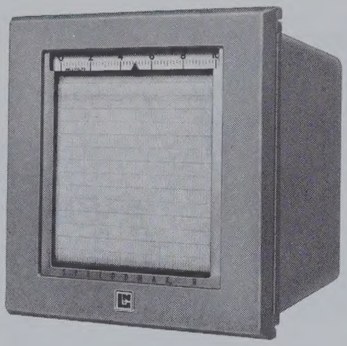
CARRYING HANDLE
LINE CORD
RUBBER FEET
WIRE SUPPORT STAND

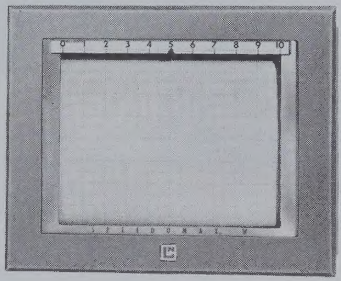
CONVENIENCE OPTIONS (H & W)

TILTING CHART TABLE AND TEAR-OFF DEVICE
LIFT-OFF DOOR
FLUORESCENT ILLUMINATION OF CHART AND SCALE (G ALSO)
NON-GLARE GLASS
DOOR LOCK
LEGEND PLATE
UNIVERSAL BINDING POST INPUT TERMINALS



SPEEDOMAX H AND W MILLIVOLT RECORDERS





For many research and production applications where a compact, electronic potentiometer is needed to measure millivolt output, Speedomax H or W millivolt recorders will provide a reliable, economical record of emf.

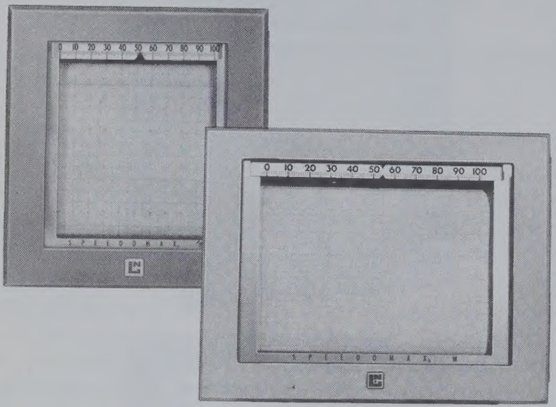
Standard recorders with a range of 0 to 10 mV offer wide flexibility where one instrument must be used interchangeably with a variety of primary elements, and calibration to a specific measurand would be a limitation; or on experimental applications where specific calibration at the L&N plant would be impractical.

OTHER RANGES AVAILABLE—Standard Speedomax H Millivolt Recorders are available with any span from 1 mV to 1000 mV. Ranges of 0 to 1, 0 to 2, 0 to 5, −5 to 0 to 5, 0 to 10, 0 to 25, 0 to 50, and 0 to 100 mV are available on standard delivery. Speedomax H thermocouple recorders are offered for use with various thermocouples. Sixty-eight different ranges are available on standard delivery; others can be supplied on order. Similar recorders are available for use with other temperature measuring elements.

Speedomax W Recorders can be supplied with one of a number of standard ranges for thermocouples or millivolts. Field conversion from one range to another is a simple procedure of replacing scale, chart and plug-in range card.

Type	Catalog Number	Chart Width, Inches	Span-Step-Response Time, Seconds	Range, Millivolts	Price
Millivolt Recorder (H)	300-932-000-0044-6-006-156	6½	1	0-10	$745.00
Millivolt Recorder (W)	500-932-000-0044-6-006-156	9⅞	1	0-10	895.00

SPEEDOMAX H AND W COMPACT AZAR® RECORDERS



Temperature, stress, strain, position, vibration, and percent concentration (by gas chromatography) are some of the variables you can measure and record with a compact Speedomax H or W AZAR (Adjustable-Zero, Adjustable-Range) recorder. You'll find the versatility of these recorders ideal for a variety of applications in research and testing laboratories.

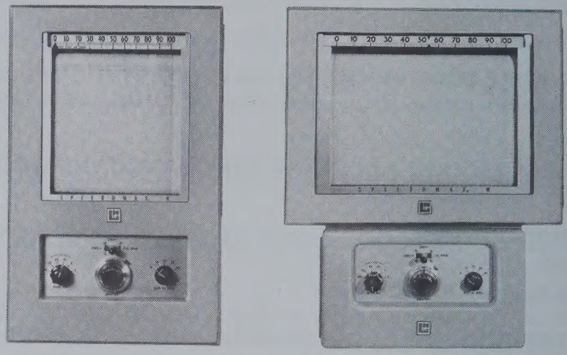
Equipped with independent zero and span controls individually powered by mercury cells, they permit you to select any calibrated span between 0.3 and 50 millivolts and any zero suppression between −50 and +50 millivolts. A Range-Control Panel, mounted inside or outside the recorder case, contains the zero and span-adjustment knobs, together with toggle switches for "±Zero", "Run-Calibrate", and "Maximum Span". By means of these controls, you can calibrate the instrument to suit the particular test parameter with the transducer in use. The measuring circuits are designed to minimize current drain from the mercury cells, assuring long life.

Chart speed is 6″ or 60″ per hour, selected by switch.* Each recorder is equipped with universal binding-post input terminals, a carrying handle, line cord and rubber feet for portability and bench operation.

Type	Catalog Number	Chart Width, Inches	Span-Step Response Time, Seconds	Zero Adjustment, Millivolts	Span Adjustment, Millivolts	Price
Adjustable-Zero, Adjustable-Range Compact Portable Recorder (H)	300-462-000-1062-6-360-006-156-521-522-523-519	6½	1.0	±50	0.30 to 50	$930.00
Adjustable-Zero, Adjustable-Range Compact Portable Recorder (W)	500-462-000-1062-6-360-006-156 521-522-523-519	9⅞	1.0	±50	0.30 to 50	1,080.00

**Suggested speeds; many other speeds are available, contact your local L&N office.*

SPEEDOMAX H AND W CALIBRATED AZAR RECORDERS



Like the compact AZAR recorders, temperature, stress, strain, position, vibration, and percent concentration (by gas chromatography) are some of the variables you can measure and profile with a Speedomax H or W calibrated AZAR (Adjustable-Zero, Adjustable-Range) recorder.

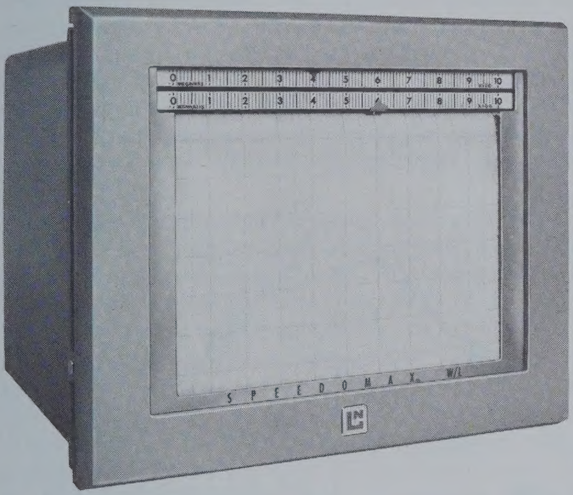
Providing any calibrated span between 0.67 and 100 millivolts and any zero suppression or elevation between −50 and +50 millivolts, the AZAR recorder is supplied with a "span and zero" module which places all calibrating controls at your fingertips; no adjustment need be made inside the recorder case. This permits you to quickly select the optimum range span for the measurement to be made. Span adjustment is easily made by means of a six-position switch with continuously adjustable attenuation at each switch position to provide continuously calibrated spans. Zero suppression or elevation is switch-selected and can be continuously adjusted for values between steps. As a result, the part of the reading significant to the measurement is spread across the full chart width, while the balance is suppressed off scale.

Chart speed is 6″ or 60″ per hour, selected by switch.* Each recorder is equipped with universal binding-post input terminals, line cord and wire support stand for portability and bench operation.

Type	Catalog Number	Chart Width, Inches	Span-Step Response Time, Seconds	Zero Adjustment, Millivolts	Span Adjustment, Millivolts	Price
Adjustable-Zero, Adjustable-Range Calibrated Laboratory Recorder (H)	300-661-000-0186 6-360-006 156-522-526-519	6	1.0	±50	0.67 to 100	$1,295.00
Adjustable-Zero, Adjustable-Range Calibrated Laboratory Recorder (W)	500-661-000-1321-6-360-006-156-522-526-519	9½	1.0	±50	0.67 to 100	1,445.00

**Suggested speeds; many other speeds are available, contact your local L&N office.*

SPEEDOMAX W/L 2-PEN RECORDER



The Speedomax W/L 2-Pen Recorder provides two completely independent measuring and recording systems in one compact case. It enables you to compare or contrast two related variables, using the same or different types of primary elements.

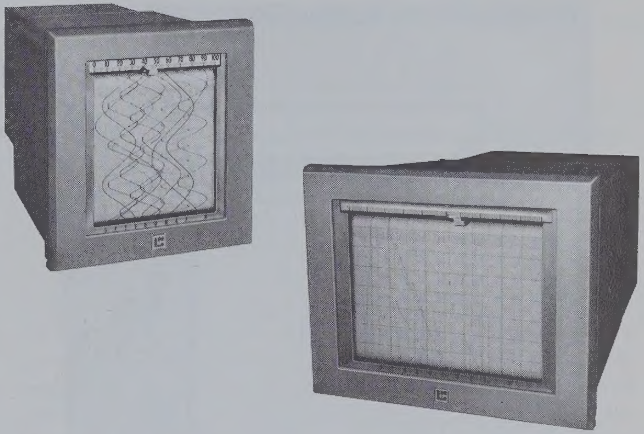
This new recorder embodies many advanced design concepts, both electrical and mechanical. All-solid-state amplifiers, input filtering and shielded circuitry provide high common-mode and transverse rejection. Twin solid-state amplifiers use all-silicon transistors for optimum dependability. All moving parts—chart-drive motors, alarm and control contacts, slidewires and balancing motors—are readily accessible.

Independent pens travel the full 9⅞-inch chart span. Half travel on each pen is available for mirror images. Dependable capillary-pen systems with large ink supplies assure clear, intelligible records. A new chart-drive assembly makes chart replacement easy and convenient. Chart speed is 6″ or 60″ per hour, selected by switch.*

Type	Catalog Number	Chart Width, Inches	Span-Step Response Time, Seconds	Range, Millivolts	Price
2-Pen Recorder (W/L)	702-30-30-000-000-0193-0044-6-ME000	9⅞	1.0	0 to 1; 0 to 10	$1,745.00

**Suggested speeds; many other speeds are available, contact your local L&N office.*

SPEEDOMAX H AND W MULTI-POINT MILLIVOLT RECORDERS



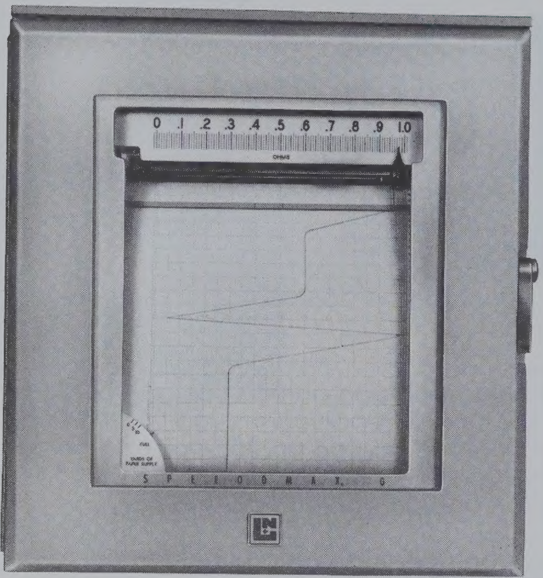
The Speedomax H 12-point recorder permits profiling up to 12 points on a chart only 6½″ wide. Where a wider chart is desired, the Speedomax W recorder is available for up to 12 or 24 points.

Both recorders feature CLEERTREND™ printing—a completely new design approach to multi-point recording. With Speedomax H and W, it gives you new clarity of data, new flexibility of application, new convenience and new economy.

Standard printing for each channel is a sequence of dots only, in one of six colors, with a numbered dot printed periodically. The high speed of the CLEERTREND printer taps out non-blurring records and every dot and number is sharply defined. A simple screwdriver adjustment permits changing from periodically numbered dots to all numbered dots, or to dots only. The number of points can be decreased simply by changing the position of an electrical connector at the relay board and replacing the printwheel and the print-wheel index (and inkwheel, if necessary).

Type	Catalog Number	Chart Width, Inches	Span-Step Response Time, Seconds	Number of Points	Range, Millivolts	Price
Multi-point Recorder (H)	315-932-000-0044-6-006-156	6½	1.0	12	0-10	$1,290.00
Multi-point Recorder (W)	515-932-000-0044-6-006-156	9⅞	1.0	12	0-10	1,440.00
Multi-point Recorder (W)	516-932-000-0044-6-006-156	9⅞	1.0	24	0-10	1,575.00

SPEEDOMAX G HIGH-PRECISION RESISTANCE THERMOMETER RECORDER



The Speedomax High-Precision Resistance-Thermometer Recorder with automatic range extension is used in research laboratories to record throughout the platinum resistance-thermometer range from −190 to +500 C with an accuracy equivalent to 0.01 C. A few of the applications of this instrument include cryoscopic determination of purity, ebulliometry, boiling range of liquids, and general calorimetry.

This instrument is an electronically-balanced Wheatstone bridge capable of utilizing the precision of a platinum resistance thermometer over a range of 100 ohms. Resistance changes in the primary detector cause an unbalance of the Wheatstone bridge. Unbalance voltage actuates a motor-driven slidewire contact which restores bridge balance. Accuracy of adjustment is 0.003 ohm or 0.01%, whichever is greater.

Through the use of special precautions such as thermostating the important bridge coils, humidity compensation of chart-paper width, etc., temperature changes in the order of 0.01 C are indicated and an accuracy in the order of 0.02 C may be achieved with a 25-ohm thermometer.

Although the full range of the recorder is 100 ohms, a range-extension mechanism utilizes the entire 9″ chart width to record a 1-ohm resistance change. The mechanism prints whole numbers of measured resistance in the left margin at 1-minute intervals, while fractional amounts are recorded on the chart by the recorder pen.

OPERATION—This instrument is an electronically-balanced Wheatstone bridge capable of utilizing the precision of a platinum resistance thermometer over a range of 100 ohms. Changes of resistance in the primary detector cause an unbalance of the Wheatstone bridge. Unbalance voltage controls a motor-driven slidewire resistance which restores the bridge balance. This instrument provides a range of 0 to 1 ohm on the continuous slidewire readable to 0.001 ohm. Extension of the 1-ohm range to a total of 100 ohms is accomplished by two automatic decades.

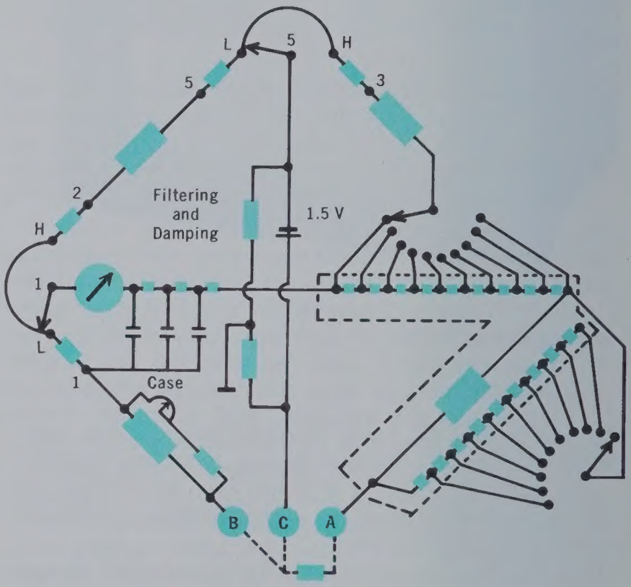


Fig. 1—High-Precision Resistance Thermometer Recorder

As shown in Fig. 1, a double-slidewire bridge circuit is used. Since the primary detector is inserted in the same arm of the bridge as the adjustable resistors, the balancing operation is a substitution method. Bridge sensitivity, therefore, is nearly constant over the entire range of the instrument. Since values of the bridge arms are also essentially constant, a fixed "Wagner ground" is connected across the battery terminals to bring the electronic detector to ground potential for stable operation. The two slidewires used in the bridge circuit are mounted on a single disk and are mechanically linked to the recorder pen.

Type	Catalog Number	Chart Width, Inches	Span-Step Response Time, Seconds	Accuracy. Rating	Range, Ohms	Price
High-Precision Resistance-Thermometer Recorder	69812-P9 -Q3-0863	9	3	±0.01% or 0.003 ohm	0 to 100	$5,185.00

DIGITAL READOUT OF LABORATORY INSTRUMENTS

ADVANTAGES OF AUTOMATED READOUT

There is an increasing requirement in many laboratories for instruments with provisions for automated readout. Among the advantages are error reduction, higher testing speeds, and more efficient use of skilled labor. Other advantages include:

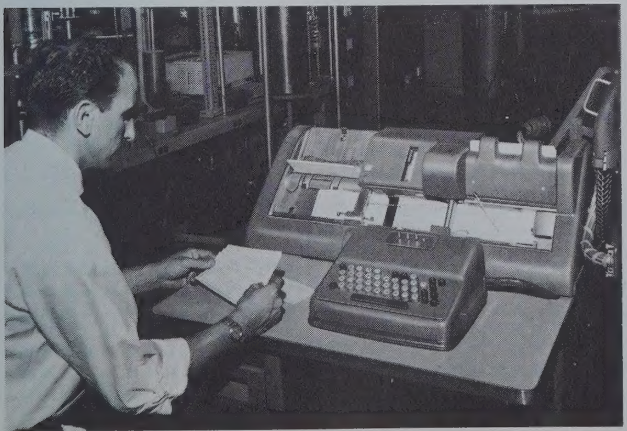
DATA COMPUTATION—Mathematical computation to provide correction data, solution of equations, the application of temperature coefficients, interpolation of data between checked points, and integration of drift curves can be performed from mechanically stored data.

DATA STORAGE—Machine retention of correction data permits the development of an instrument recall system to insure proper recalibration intervals, the comparison of several instruments to derive system errors, and the application of correction data on a semi-automatic basis to measurements made with a suitably calibrated instrument.

REPORT PREPARATION—Where a series of measurements is involved, such as correction data on a potentiometer, temperature coefficient data, or thermocouple calibrations, the automatic type-out of reports can be a worthwhile convenience, especially where the work-load levels have out-paced qualified manpower capabilities. Prepared information on format can be included to simplify production reports of a repetitive nature.

DYNAMIC MEASUREMENTS—Drift and temperature coefficient data, for example, may require shorter measurement intervals than can be obtained when data is recorded by hand.

HIGHER ACCURACY—Random errors can be reduced through averaging of a number of measurements of the same value or by establishing a carefully developed program of making automatic measurements.



INSTRUMENTS WITH PROVISIONS FOR AUTOMATED READOUT

Certain L&N instruments are available with provision for remote, electrical (sequential) readout. They are the:

4398	Six-Dial Double Ratio Set
4399	Seven-Dial Precision Potential Divider
7565	Standard-Cell Comparator
7556	Six-Dial Potentiometer
8072	Type G-4 Mueller Bridge

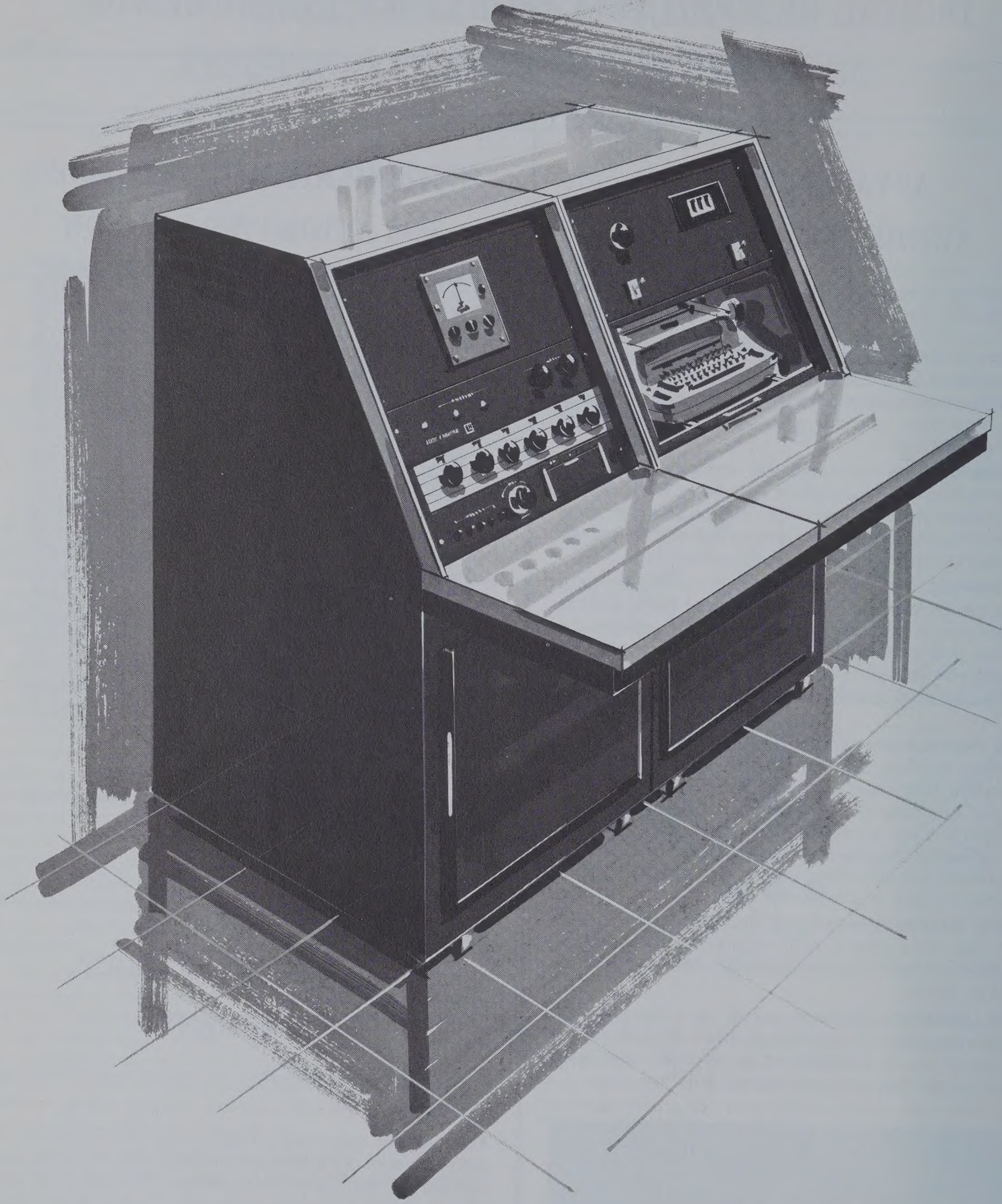
In each case the measuring instrument is balanced in the normal manner. However, as each measurement is completed, the operator pushes a button to automatically produce punched or typewritten records. This recorded information can include the reading, as well as associated information. Automated readout is accomplished by utilizing extra decks on each of the Type 31 switches.

A programming device sequentially selects the appropriate decades, and the information is automatically entered on the recording equipment. One readout assembly can measure from any of the above instruments. Provision of wired decks to an external connector for automated readout is designated by adding a suffix "-R" to the List Number of the instruments named above.

AUTOMATED READOUT EQUIPMENT

This chapter describes a tape-punch and an IBM typewriter readout console which are available for automated readout of the listed instruments. The punched-tape output provides maximum flexibility in that it can feed converters which will print, will punch cards, or punch modified tapes. In addition, two tapes can be combined in some machines for the inclusion of instructions, covering such details as tab spacing, typewriter column headings or paragraphing. Other readout equipment, such as IBM card punches, Flexowriters or printers can be provided if desired. For further information, contact your L&N sales representative.

Provision for future addition of automated readout apparatus can be obtained by adding an "-R" suffix to the appropriate instrument List Number.



MEASUREMENT EQUIPMENT

The measuring equipment may be mounted in a console assembly in which all components are contained in one "high-boy" console, factory-wired and checked (see description in Laboratory Furniture chapter) or may be mounted in a facility cabinet, which is supported on a "low-boy" console at the height of the readout console. In situations where field conversion of an existing instrument is desired for automated readout, a wiring harness is available.

Listed below are the console assembly, facility assembly and wiring harness for the 7556 Potentiometer and 4399 Potential Divider. These represent just two of our many custom capabilities; tell us your application so we can meet your specific needs.

FOR 7556 SIX-DIAL POTENTIOMETER

CONSOLE ASSEMBLY

7556-A21-R☐ Console which includes:

1 7556-1-R Six-Dial Guarded Potentiometer with extra wired switch decks

(Note: "-R" feature specifies that decks are to be supplied wired to rear-mounted connector)

1 9838-1 Null Detector
1 7308 Unsaturated Standard Cell
1 9878 Power Supply

PRICE—On request.

FACILITY ASSEMBLY

1 7556-A13-R☐ Facility

PRICE—$4,980.00.

1 Low-boy console (optional)

PRICE—$400.00.

WIRING HARNESS

Wiring-harness kit for field installation of readout wiring in existing 7556 Potentiometer.

PRICE—$90.00.

FOR 4399 SEVEN-DIAL PRECISION POTENTIAL DIVIDER

CONSOLE ASSEMBLY

4399-A20-R☐ Console which includes:

1 4399-1-R Seven-Dial Precision Potential Divider
1 9834-1 Null Detector
1 9876-1 Power Supply

PRICE—On request.

FACILITY ASSEMBLY

1 4399-A11-R☐ Facility

PRICE—$4570.00.

1 Low-boy console (optional)

PRICE—$400.00.

WIRING HARNESS

Wiring harness kit for field installation of readout wiring in existing 4399 Potential Divider.

PRICE—$90.00.

READOUT EQUIPMENT

Leeds & Northrup can provide a tape-punch readout console or a typewriter readout console (illustrated). All components are mounted and wired in a "high-boy" console, which is equipped with casters, front wheel locks and leveling screws for rigid mounting. Front and rear doors and a Formica work surface are provided. Provision is made to enable the readout console to be bolted to the measuring console to form a continuous, integrated assembly.

These consoles are designed specifically for use with 19" panel-mounted instruments. A selector switch is included to allow the operator to manually select which instrument is to be read out. Six input receptacles are included of which two are active and identified (7556 and 4399) at the switch. These receptacles are pin-coded to prevent connecting an instrument to the wrong receptacle.

The system provides for 3 digits of "static" data to be selected and entered through the use of thumbwheels. This static data could identify the serial number of the instrument being tested or, in the case of the 7556, whether Input A or Input B is being read out. A separate character is automatically entered to identify the type of instrument being monitored, and a coded character can be manually entered to indicate that the readout data should be disregarded because of operator error or other reasons.

The solid-state programmer is designed to sequence through 15 steps of readout, allowing for future expansion from the maximum of 11 steps used at this time. With the 0000 step being used as the start position, the programmer runs asynchronous with the readout device. Readout is started by depressing the single "start" button which resets all relays to the zero state. When the button is released, pulse from the multivibrator begins advancing the counter at a rate of 100 milliseconds per count. (This rate can be varied to suit the speed of the readout device.) For each step of the counter, a relay is picked up and power is applied to the solenoids of the readout device. To obtain another readout the start button must be pushed again.

TAPE-PUNCH READOUT CONSOLE "-R4"

RELAYS—Converts "10" through "15" positions of 7556 first dial to standard sequential readout.

SELECTOR SWITCH—Connects switch-deck commons of instrument to be read out. Selector switch has two positions shown—7556 or 4399. (Switch has four additional positions for future use with other instruments.)

THUMBWHEELS—Three included. Permit entry of manually-set "static" data as three-digit number.

POWER SUPPLY—48 V d-c. Energizes programmer.

PROGRAMMER—Release of "start" button pulses multivibrator advancing counter through 15 steps (seven digits reading, one digit multiplier, three digits static and four for future capacity).

START BUTTON

MATRIX BOARD—Receives signal from switches (decades or thumbwheels), converts to "Excess 3" code and pulses appropriate solenoids of readout device.

VOID BUTTON—Supplies signal which results in readout of coded character, indicating voiding of previous reading.

READOUT DEVICE—Tape punch provides paper tape with "Excess 3" code suitable for computers so programmed. (Other codes available).

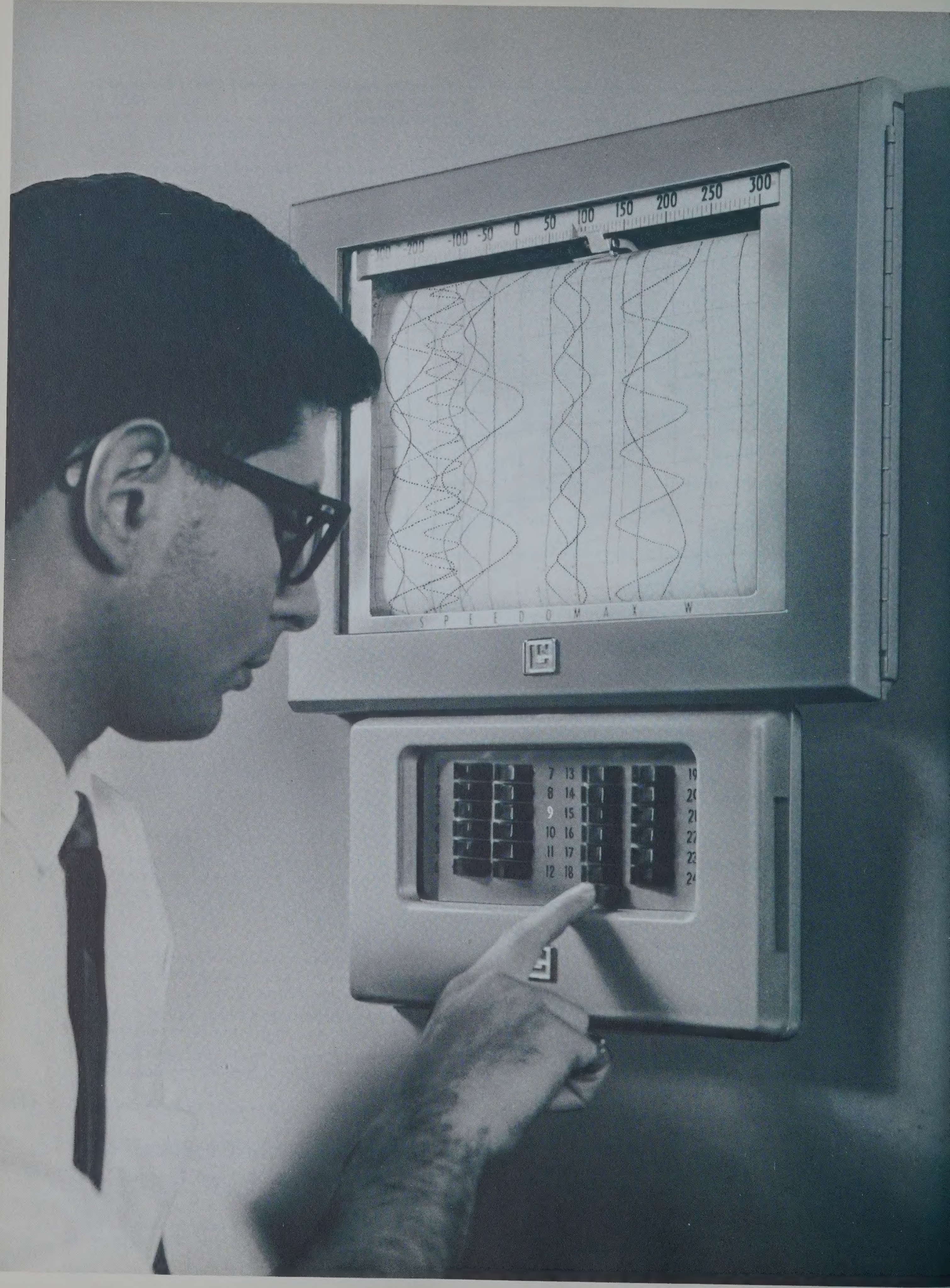
PRICE—On request.

TYPEWRITER READOUT CONSOLE "-R2"

Same as Tape-punch Readout console described above, except:

READOUT DEVICE—IBM typewriter.

PRICE—On request.


-300 -200 -100 -50 0 50 100 150 200 250 300
SPEEDOMAX W
7 13
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9 15
10 16
11 17
12 18

I

INSTRUMENTS FOR SPECIALIZED APPLICATIONS

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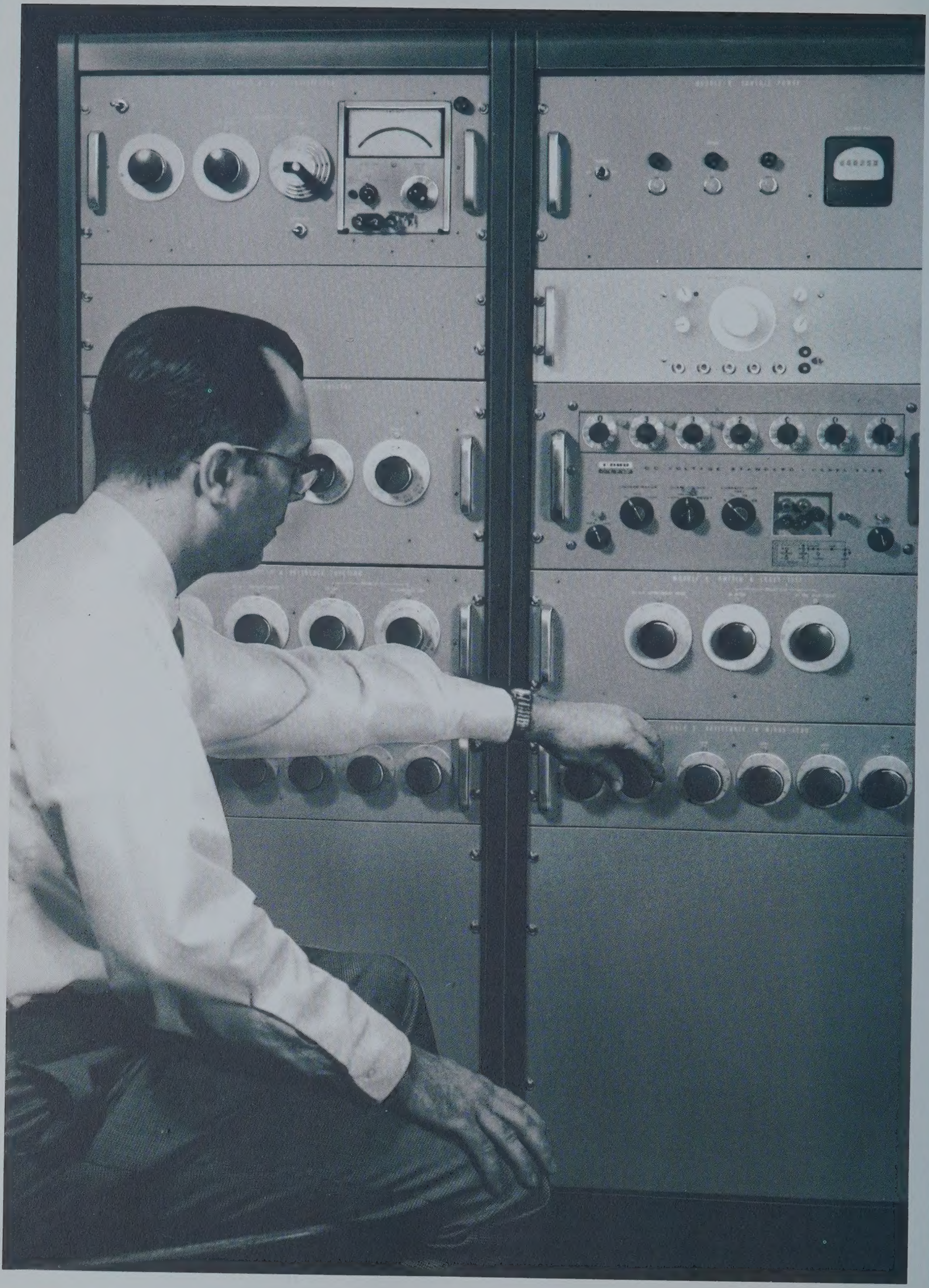
Cryogenic Calibration Facility I-3
Drop Calorimeter I-4
Special Shunt I-5
Meter-Lab Calibration Facility I-6
Potentiometer Calibration Facility I-7
Cioffi Fluxmeter I-8
Capacitance Bridge I-9
Limit Bridge I-9



INSTRUMENTS FOR SPECIALIZED APPLICATIONS

For many years, Leeds & Northrup has worked closely with research scientists, educators, and technical specialists to produce, on special order, custom-built instruments for special applications . . . an activity which has made notable contributions to the advancement of the art of measurement. This capability to provide custom instrumentation to fill our customers' requirements for highest accuracy measurements in highly specialized applications is an important means by which L&N maintains a position of leadership.

This chapter describes a variety of such specialized instruments. In addition to suggesting the applicability of these or similar instruments to your requirements, this listing is also intended to convey the scope of Leeds & Northrup's capability for developing, building, and testing a wide range of custom instrumentation for electrical measurements.

These specialized instruments include:

a) modifications of basically standard instruments

b) console packaging of existing instruments to provide complete measuring facilities

c) totally new designs.

Descriptions of the following instruments appear in this chapter:

Automated Mueller Bridge for resistance-thermometer calorimetry

Cryogenic Calibration Facilities for low-temperature calibration of resistance thermometers

Drop Calorimeter for determination of heat content of oxides and other compounds

Special Bath and Highest-Precision Shunt for use in electron spectroscopy

Meter-Lab Calibration Facility for electric utility application

Potentiometer-Recorder Calibration Facility

Cioffi Fluxmeter for testing magnetic properties

Capacitance and Conductance Bridge for wide-range, high-resolution impedance measurements

Automatic Per-Cent Limit Bridges for testing resistance of production parts

Your nearby L&N Field Engineer will be glad to discuss your requirements for such custom-built apparatus, and to submit recommendations, estimates and target specifications according to our skills and production capabilities. Or, if your prefer, write us directly, at Philadelphia.

Even if it is not listed or described in this catalog, there is a good possibility we've successfully built apparatus to do your specific job.

AUTOMATED MUELLER BRIDGE FOR CALORIMETRY

BRIDGE CONTROL UNIT
LEEDS & NORTHRUP
AUTOMATED BRIDGE

This unusual resistance-thermometer bridge has been developed by Leeds & Northrup for use in a specific calorimeter application. The circuit is basically a Type G-3 Mueller Bridge with a resolution of 10 microhms (better than one part in 10^7) and a range of 0 to 2500 ohms. The unusual features of the bridge are:

a) Diverse logic circuits are applied to follow automatically the changes of thermometer resistance at rates normally encountered.

b) An electronic null detector is utilized which is capable of resolving 0.02 μV in the presence of many forms of interference of substantially high level (voltage from thermal agitation, thermal emf, persisting effect of previous unbalance, and power frequency pickup).

c) Special mercury-wetted switches are used for thermometer reversing to provide automatic compensation for lead-resistance unbalance.

d) Provision is made for storage of readings and transfer to a card punch or other related equipment without interrupting the bridge balancing action.

OPERATION

When the bridge is tracking a thermometer, the unbalance detector first observes and decides the direction of unbalance. The decision is made for a "repeat" or "reversal" of the previous decision. A series of repeats indicates the bridge is not keeping up with the changing thermometer resistance, and when a "critical count" of repeats is reached, the bridge makes an "upshift" to the next larger step size. A series of "reversals" indicates that the bridge is bracketing the thermometer resistance; a "critical count" of reversals indicates that the rate of resistance change of the thermometer has become small enough so that it can be tracked by the bridge after making a "downshift" to the next smaller step size. In this manner the equipment automatically decides how fast or slow it should operate (which dial to turn) to keep pace with temperature.

The following quantities which may vary during a measurement are indicated on a continuous centralized visual display, and can be recorded on punched cards:

Clock time
Bridge resistance
Thermometer connection (normal or reversed)
Compensating resistance (for lead unbalance)
Count of repeats
Count of reversals
Rate (identifying number)
Detector decision
Shift (up or down)

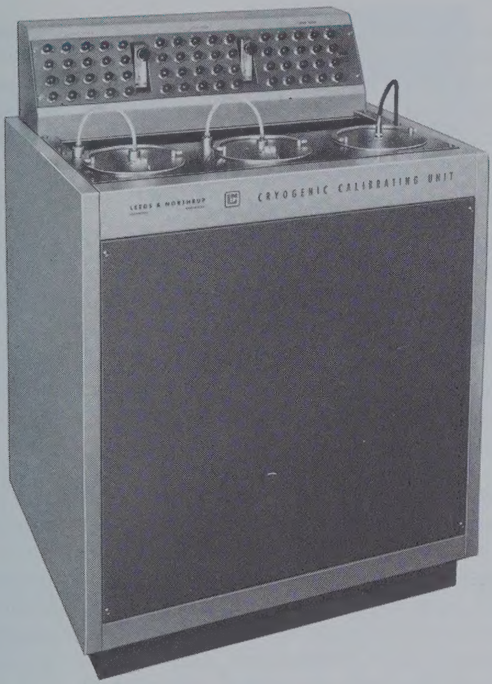
COMPONENT EQUIPMENT

The automated bridge equipment is housed in two consoles. The larger unit contains the resistance-thermometer bridge, a separate temperature control unit to maintain critical resistors in the measuring circuit at a constant temperature, and a source of d-c current (battery). This unit also contains the unbalance detector circuit and decision amplifier, the program logic for providing timed sequence for the measuring and recording functions, the actuator units with rotary solenoids for moving the switches, and the shift logic to initiate such actions as upshifts, downshifts and thermometer reversals.

The smaller "control unit" provides manual control, digital readout, data storage, and communication with the external card punch.

An "exerciser" keeps the mercury-wetted switches in periodic operation at a slow cycle when the bridge is not making a measurement. This maintains a fresh mercury surface and a state of readiness for startup at the beginning of an experiment.

CRYOGENIC CALIBRATION FACILITIES



L&N has developed two approaches to a cryogenic transducer calibration system. Both approaches utilize a fixed-point apparatus, or cryostat (shown), and a measuring system with automatic readout. In the first case a Mueller-bridge circuit is used; the more recent approach utilizes the potentiometric null method, with a Mueller Bridge provided for optional manual observation.

MUELLER-BRIDGE METHOD

This L&N Cryogenic Calibration Facility provides capability for calibrating four resistance temperature transducers at one time against a standard platinum resistance thermometer at the temperature of boiling oxygen (90 K) and boiling nitrogen (77 K) to an accuracy of ±0.01 F, and at the sublimation temperature of solid CO_2 (194.6 K) to an accuracy of ±0.02 F. The readout equipment measures the resistance of four-lead thermometers over the range of 0 to 2500 ohms with a readability of 0.0001 ohm or six digits of resistance value, whichever is larger. It provides automatic digital printing of measured data for twelve unknown and three standard temperatures, with resistance values digitized in lights. Limit of error is:

0.0002 ohm up to 10 ohms;

0.002% from 10 to 100 ohms;

0.005% from 100 to 2500 ohms.

THE FIXED-POINT APPARATUS is furnished in a cryogenic cabinet containing N_2, O_2, and CO_2 Dewars in which are suspended copper equalizing blocks drilled to accept resistance thermometers. Thermometer leads are connected to binding posts on the sloping terminal panel, from which point they are connected through multiple-conductor cables to the readout apparatus. The N_2 and O_2 baths reach equilibrium within ±0.01 F in five minutes and remain stable for one hour. The CO_2 cools down to equilibrium in less than 15 minutes and is sustained within ±0.02 F for at least 30 minutes. This constancy is important since it enhances uniformity of temperature between the standard and unknown thermometers.

THE MEASURING SYSTEM AND READOUT CONSOLE consists of a special Mueller resistance-thermometer bridge circuit providing 20 to 50 ppm accuracy over the wide range of resistances of thermometers to be measured. By utilizing comparison techniques, the accuracy of calibration of the unknown is limited principally by the uniformity achieved between them and the standards. Mercury-wetted switches for selecting thermometers and for several of the critical bridge decades provide low, constant switch resistance. Electro-mechanical switch actuators of the rotary-solenoid type provide switch operation in about 70 milliseconds per step. Logic circuits to direct thermometer selection, bridge balancing and readout operations utilize high-speed solid-state elements. A high-gain d-c amplifier serves as null detector and decision-making unit in the balancing system.

After manual selection of a thermometer by the operator, the system will automatically balance the bridge and print out test information in less than one minute, depending upon the resistance range over which the operation is required to travel to attain balance. Measured information is displayed in digital form as the balancing operation proceeds; when final balance has been obtained, results are printed out on an IBM typewriter.

POTENTIOMETRIC NULL METHOD

A similar cryogenic transducer calibration system utilizes the "potentiometric null method". The basic principle is that the potentiometer current is adjusted to such a value that the dial readings at balance will be direct reading in ohms with normal current through the transducers. Two 7556-1-R Potentiometers are used—one for a standard sensor and one for the test sensors. Each potentiometer has its own null detector. This arrangement reduces dial manipulation and potentiometer current changes. The standards are NBS-calibrated thermometers; a germanium probe for the range 4 K to 20 K and an 8164 Platinum Thermometer for the range 20 K to 100 K. A manually-operated Type G-3 Mueller Bridge is provided for built-in cross-check calibration.

In operation, after a given temperature has been established in the cryostat, the function switch is set to the appropriate standard, and the corresponding potentiometer is balanced. The function switch is then set to one of the four test thermometers and the other potentiometer is balanced. The typewriter printout system is actuated, and the resistances of both the standard and test thermometers are automatically printed, with automatic decimal positioning and thermometer identification. Overall system accuracy of better than ±0.2 K is guaranteed over the entire range of 4 K to 100 K.

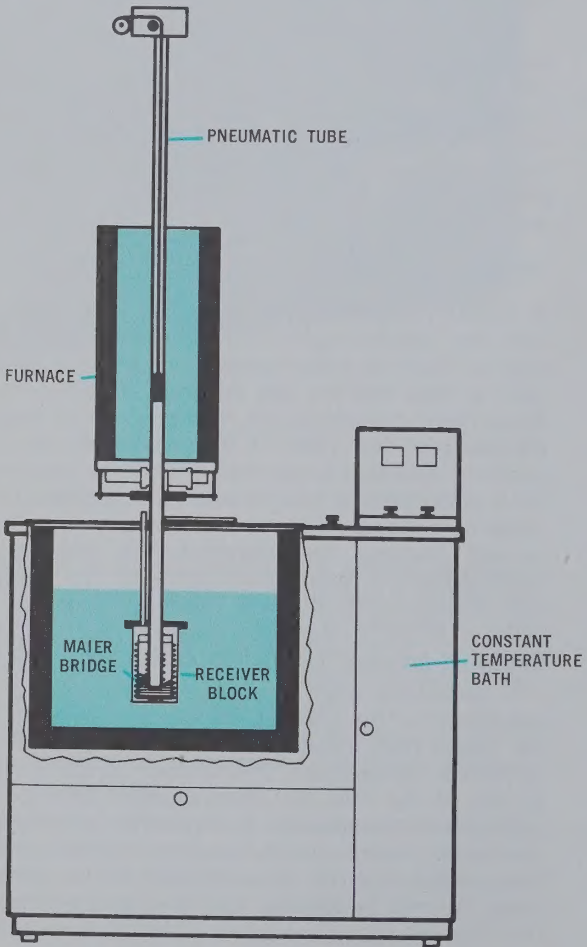
The measurement and readout system is housed in a single console, with components positioned for maximum convenience and simplicity of operation.

DROP CALORIMETER

This Drop Calorimeter is used in determining heat content of oxides and other compounds up to 1650 C.

APPLICATION

A sample is loaded into a capsule suspended within the vertical isothermal furnace. When the temperature of the sample reaches the desired level, as determined by a calibrated platinum, rhodium-platinum thermocouple, the furnace and receiver gates are opened and a small amount of dry ice is inserted in the receiver. The small drop in receiver temperature induced by the dry ice was predetermined to be approximately equal to the anticipated rise above the bath temperature. This permits more precise receiver calibration. After the receiver has stabilized, the sample-dropping system is triggered. This allows the sample to free-fall into the calorimeter receiver, contained within the controlled-temperature oil bath. A Maier bridge, wound on the calorimeter receiver, accurately determines the temperature rise of the receiver, and thus the sample heat content. The temperature drop and the mass of the sample can be used to determine enthalpy, and thus specific heat, of the sample.



COMPONENT EQUIPMENT

This Drop Calorimeter consists of the following components:

a vertical, tubular, isothermal furnace with a sample-dropping mechanism and control system.

a constant-temperature oil bath capable of maintaining temperature uniformity, with a constancy of ±0.001 C over the desired range.

a calorimeter receiver assembly.

FURNACE—The heating element of the furnace is a platinum-rhodium alloy which is wound non-inductively on an alumina muffle. The range of the furnace is approximately 200 C to 1650 C in air or inert atmosphere. External taps are brought out to allow the attachment of shunt resistors to minimize temperature gradients in the furnace. High-temperature insulation surrounds the furnace muffle, with protective shielding at both ends. The central part of the furnace muffle contains an isothermal zone in which temperature is maintained with a uniformity of 0.5 C.

The furnace is equipped with a sample-dropping mechanism and triggering device which allows the sample section to free-fall over approximately 75 to 80% of the length of travel. Pneumatic braking occurs during the final distance to prevent jamming the capsule into the receiver.

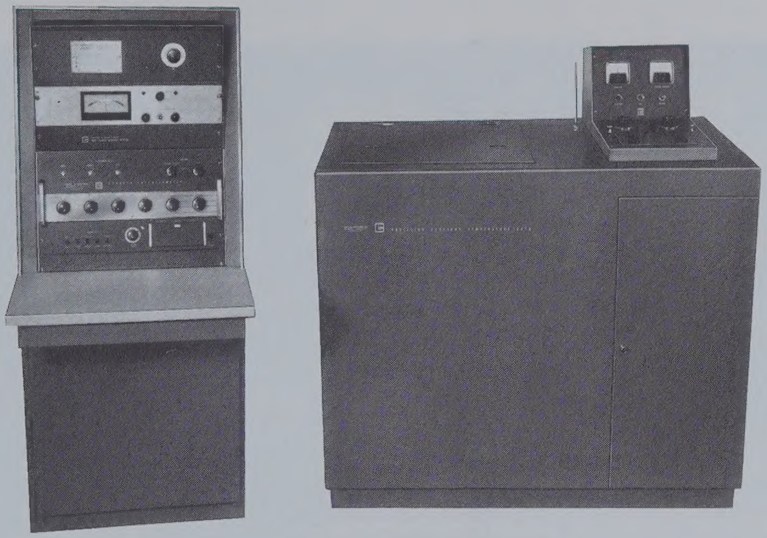
Thermocouples are used for furnace control and initial sample-temperature measurement. Automatic control permits establishing furnace temperature at each desired level with an accuracy of 1%. It includes a set-point station, a deviation amplifier, and a current-adjusting-type control station. This furnace control system is rack-mounted, with provisions for the addition of a strip-chart recorder. A separate thermocouple is used for the temperature measurement, the most important function of the controller being to hold temperature constant once equilibrium is attained.

RECEIVER ASSEMBLY—The receiver assembly is submerged in a constant-temperature oil bath, and consists of a calorimeter block assembly with a submarine can assembly. A Maier bridge is wound bifilarly and non-inductively on the recessed portion of the calorimeter block and is connected to the readout equipment. A calibration heater is wound bifilarly external to the calorimeter block.

CONSTANT-TEMPERATURE OIL BATH—The entire receiver assembly is immersed in an L&N 8401 Constant-Temperature Oil Bath. Operating range is 20 to 60 C, with a stability within ±0.001 C over a period of 24 hours. The oil-bath assembly consists of a temperature control system, dual heaters, an oil-flow system, a cooling system, work space and a control console.

SPECTROMETER MAGNET CURRENT-MEASURING SYSTEM

(With Special Bath and Highest-Precision Shunt)



This unique system was constructed by Leeds & Northrup for the measurement of high current values to the highest possible precision. It measures voltage across a known resistance, current being derived by applying Ohm's Law. A special set of low-value, four-terminal resistors (shunts) was constructed using manganin strip with the same temperature and stability characteristics as the Grade A wire used in the 4210 Thomas-type One-Ohm Standard. This is unusual, as shunts are normally made of shunt-grade material designed to peak in resistance near 40 C. The shunts were arranged in symmetrical fashion and mounted in an 8401 Oil Bath whose temperature is set to the peak point of the temperature coefficient curve for the selected manganin strip. Current is then passed through the shunts and the voltage drop across the desired section is measured with a six-dial potentiometer.

APPLICATION

The specific application for which this precision current-measuring system was constructed involved measuring the direct current passing through a set of air-cored coils in a magnetic electron spectrometer. The magnetic field generated is directly proportional to the current through the coils. The accuracy with which the momentum of the electrons may be measured is mainly limited by the current stability of the power supply and the accuracy with which the current ratios may be measured. This measuring system permits the determination of the ratio of electron energies to a few parts per million. The range of current to be measured is from 1 to 200 amperes in three current ranges, which are determined by the characteristics of the power supply. Each range is divided into 2^{18} (262,144) discrete current steps. During any given experiment, as many as 1000 steps within a range may be stepped to examine the number of events per unit time that take place for the current interval. When points of interest have been determined using this stepping technique, the measured absolute value of current and the current ratios between the points of interest will determine the momentum and electron-energy ratios involved.

To accomplish this, the overall current-measuring system will have to be accurate to within 50 ppm of reading + 30μV over the range of 1 to 200 amperes. The current ratio of any two successive current measurements for any two currents in the range 2 to 200 amperes will be repeatable to 10 ppm for eight hours. For currents less than 2 amperes the accuracy required is 2/I x 10 ppm. Measuring system resolution must be better than 10 times the smallest step.

COMPONENT EQUIPMENT

The complete current-measuring system consists of the special bath and shunt system and a six-dial potentiometer measuring facility.

SPECIAL BATH AND SHUNTS

A set of 4 four-terminal shunts with the following characteristics is mounted in a modified 8401 Constant-Temperature Bath

Section	Current Range	Resistance*	Calibration Information	
			Uncertainty	Resolution
1	1 to 12.5 A	0.024 ohm	±20 ppm	±1 ppm
2	6.25 to 25 A	0.012 ohm	±20 ppm	±1 ppm
3	25 to 50 A	0.003 ohm	±20 ppm	±1 ppm
4	50 to 200 A	0.00075 ohm	±20 ppm	±1 ppm

**Four-terminal value within ±0.04% of nominal stated.*

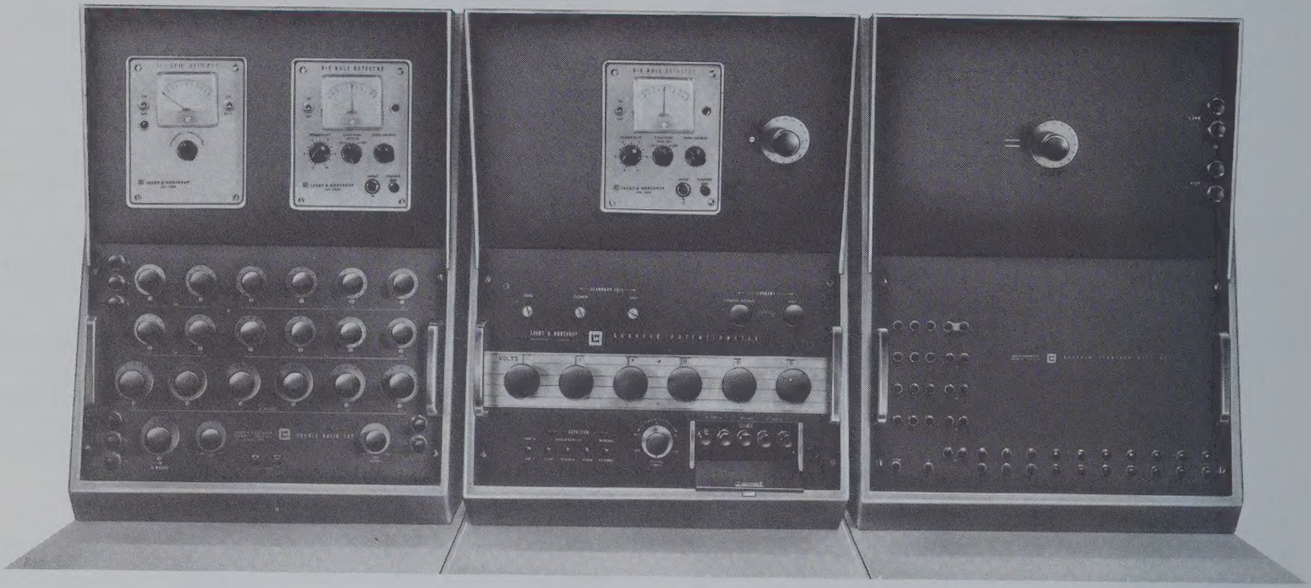
Accuracy of current measurement determined by calibration information supplied.

Change in resistance shall be less than 10 ppm per year averaged over the first three years.

POTENTIOMETER CONSOLE

7556-A21-R-B Floor Console includes a 7556-1-R Six-Dial Potentiometer wired for automatic readout, 9838-1 Null Detector, 9878 Power Supply, and a 7311 Standard-Cell Bank with switch for standard-cell selection. Measuring system resolution is 0.06 μV, or approximately 0.5 ppm of the middle range of the potentiometer.

METER-LAB CALIBRATION FACILITY



This Meter-Lab Calibration Facility combines a group of standard L&N instruments to provide a highly flexible, yet simply operated system. Each of the three measuring instruments—potentiometer, ratio set and volt box—is mounted in a convenient facility cabinet which can be removed from the five-bay floor console and easily transported for use at a remote location. Standard cells and battery are located within the console under the potentiometer facility. The floor console has both front and rear access doors and internal shelves for storing additional equipment.

Convenience features include a switch on the potentiometer for selecting each standard cell, individual null detectors for simultaneous use of potentiometer and ratio set, and a trickle-charged battery to provide auxiliary power to the standard-cell enclosure temperature control in case of power failure. A complete set of resistance standards provides power-of-ten capability from 0.001 to 1,000,000 ohms.

APPLICATION

This precision d-c measuring facility has many electric-utility laboratory applications, including:

calibrating ammeters, voltmeters, wattmeters and dynamometers

checking and certifying standard cells, standard resistors and resistance decades, volt boxes, shunts, Kelvin and Wheatstone bridges

checking Mueller bridges and slidewire uniformity

calibrating potentiometers, differential and digital voltmeters and power supplies

measuring temperature using thermocouples or resistance thermometers

measuring emf from 0.01 μV to 1500 V d-c

providing a six-dial, four-terminal resistance-box capability within a range of 100 to 1,111.11 ohms in steps of 0.001 ohm

providing reference voltages certified to 1 μV.

COMPONENT EQUIPMENT

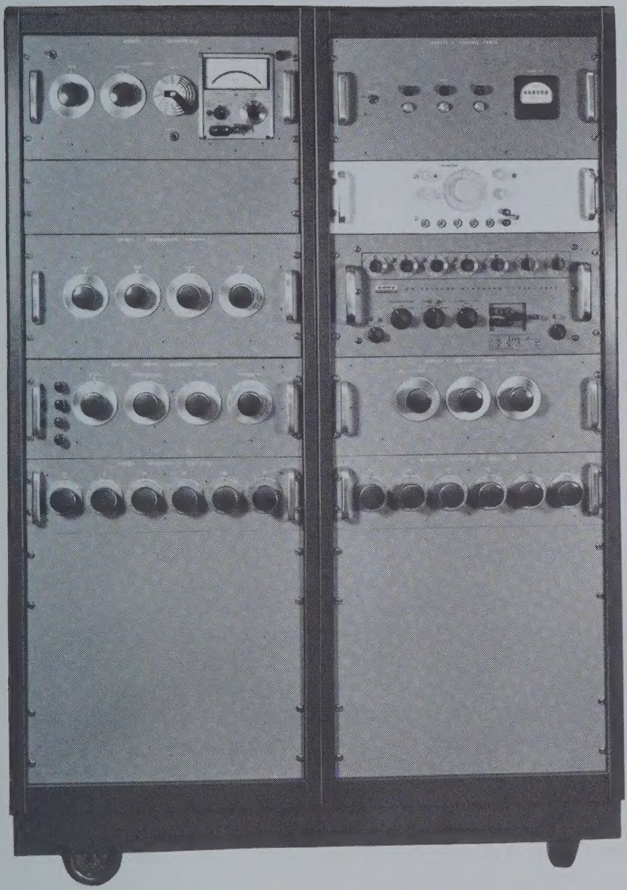
The Meter-Lab Calibration Facility consists of the following equipment, housed in a five-bay floor console:

7556-A11 Six-dial Potentiometer Facility
7594-S Guarded Precision Volt Box
4398-A11 Six-dial Double Ratio Set Facility
7311 Standard Voltage Reference
— Standby battery and automatic trickle charger

All standard resistors are accompanied by an L&N Certificate of Calibration. The complete set of resistance standards and connecting hardware comprises:

1	4223-B Reichsanstalt 0.001-ohm standard
1	4222-B Reichsanstalt 0.01-ohm standard
1	4221-B Reichsanstalt 0.1-ohm standard
1	4210 Thomas 1-ohm standard
1	4020-B NBS 1-ohm standard
1	4025-B NBS 10-ohm standard
11	4030-B NBS 100-ohm standards
1	4035-B NBS 1000-ohm standard
1	4040-B NBS 10,000-ohm standard
1	4045-B NBS 100,000-ohm standard
1	4050-B NBS 1,000,000-ohm standard
12	127287 Mercury Cup Stands
2	128436 Amalgamated copper shorting links (male)
2	128488 Amalgamated binding post terminals (female).

POTENTIOMETER CALIBRATION FACILITY



This L&N calibration facility was designed for the testing of potentiometers—especially for self-balancing potentiometric recorders. It provides switch-selected millivolt signals to simulate standard thermocouples (iron-constantan, copper-constantan, Chromel-Alumel, and platinum, 13% rhodium—platinum at 68 hot-junction temperatures. Four cold-junction circuits are also provided for checking potentiometers with built-in cold-junction compensation. A precision volt and millivolt source is incorporated to check the accuracy of instruments calibrated in terms of emf (from 1 μV to 1000 V d-c). The millivolt source is also used with the internal reference-junction compensation for temperature points other than the standard, switch-selected values. Both grounded and floated shield techniques may be used. All module front panels and all power-wiring shields are connected to a ground terminal. All low-level circuitry and interconnecting cabling are encased in floated metallic shields which are interconnected and terminated to a common shield terminal.

APPLICATION

The facility permits the operator to check the following performance characteristics of potentiometers:

calibration accuracy, sensitivity, etc. for emf or thermocouple inputs

input impedance and source-resistance tolerance

tolerance of 60 Hz a-c electrostatic interference (both common and differential modes)

transient response (response time, damping, frequency response, etc. for square sine or triangular waveforms)

chart-speed accuracy.

COMPONENT EQUIPMENT

The console consists of nine modules mounted in two 19″ relay-rack cabinets, which are bolted together and mounted on casters for ease of mobility. These modules and their functions are:

MODULE 1—RESISTANCE IN PLUS LEAD

MODULE 2—RESISTANCE IN MINUS LEAD

Provide six decades of resistance values each, for switching into plus or minus leads.

MODULE 3—PROGRAM SWITCH AND REFERENCE JUNCTION

MODULE 4—PROGRAM SWITCH AND CHART TEST

Provide seven in-line programming switches across modules 3 and 4 for selecting the features required for a given test.

MODULE 5—THERMOCOUPLE SIMULATOR

Provides four switches for dialing-in simulated temperature in degrees F or C for the type of thermocouple indicated.

MODULE 6—D-C VOLTAGE STANDARD

Provides emf values from 1 μV to 1000 V d-c.

MODULE 7—FUNCTION GENERATOR

Provides a periodic function of square, sine or triangular waveform with adjustable amplitude and frequency.

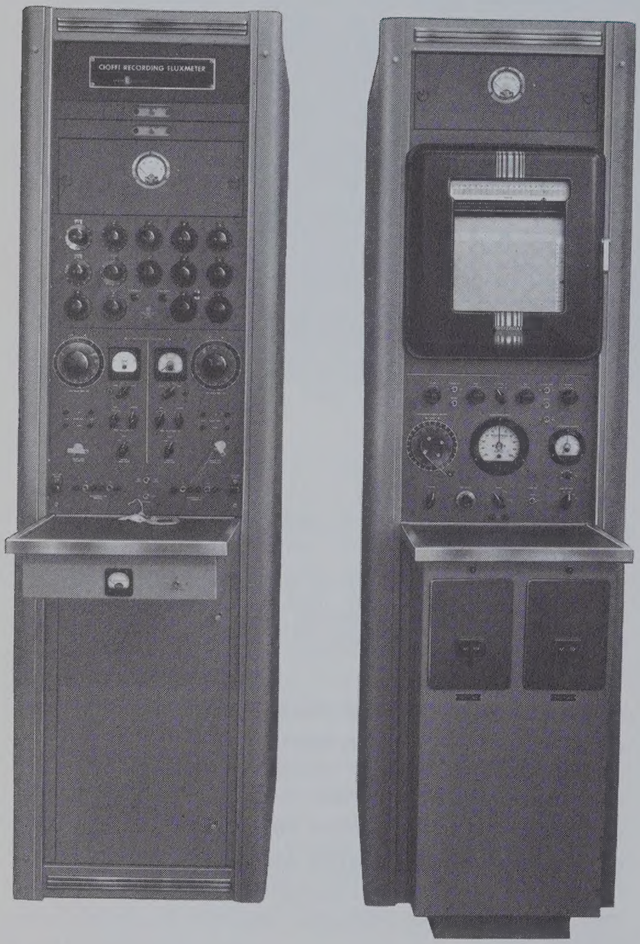
MODULE 8—A-C INTERFERENCE

Generates a-c sine-wave voltage of 60 Hz, from less than 10 mV to greater than 200 V a-c; readable by its voltmeter; amplitude and phase are settable.

MODULE 9—POWER

Supplies 3-phase or single-phase as required; elapsed-time meter is included.

CIOFFI RECORDING FLUXMETER



Designed by Dr. Paul P. Cioffi of the Bell Telephone Laboratories, the Cioffi Fluxmeter* is available from Leeds & Northrup for testing the magnetic properties of certain materials.

APPLICATION

The Cioffi Recording Fluxmeter is used as a research tool or a quality-control instrument to obtain the magnetic characteristics of materials used in:

cores of generators, motors, and transformers
magnetic memories for computers
audio and video recordings
magnetic amplifiers
relays and solenoids.

It rapidly and accurately produces magnetization curves, and both major and minor hysteresis loops, for such magnetic material samples in ring (washer or toroid) or bar form.

COMPONENT EQUIPMENT AND OPERATION

The Cioffi Recording Fluxmeter is contained in two upright cubicles. The sample of magnetic material is tested and the test results are automatically indicated in the form of a hysteresis loop on the 10″ chart of a Speedomax X-Y recorder. One component of the loop is the magnetizing force which is derived from the current through a primary winding of the sample. The other component of the loop is the flux density in the sample which is derived from the induced emf in a secondary winding on the sample. Suitable control settings relate the magnetizing force and flux density to the divisions on the chart so that a fully calibrated set of magnetic characteristics can be obtained from each hysteresis loop. In normal operation, the "X" scale indicates flux density in gausses and the "Y" scale indicates magnetizing force in oersteds. When measuring the flux density ("X" scale of recorder) of *ring samples,* an optical-electrical integrating and amplifying circuit with its controls, and an Ayrton-shunt range-control circuit, are utilized. The magnetizing force is directly proportional to the magnetizing current which is fed to the "Y" function of the recorder, as modified by an Ayrton shunt for range calibration.

When a *bar sample* is to be measured, it is placed between two large magnetizing coils and the flux-density parameter is measured by the search coil in the way same and with the same circuits as for the ring-sample measurement. Since the magnetizing force is not directly proportional to the magnetizing current, it is measured with a Chattock magnetic potentiometer and a second integrating circuit, with an Ayrton shunt for range calibration of the recorder.

Certain design considerations are necessary because of the extreme sensitivity of the circuits:

a) the optical circuits and the first stages for the amplifying circuits are mounted on a platform which is suspended from the top of the cubicle by a long spring to damp out mechanical vibrations

b) each galvanometer has double electrostatic, magnetic and thermal shields

c) the integrator-circuit controls, mounted on the panel above the desk, are both electrostatically and thermally shielded.

**A Recording Fluxmeter of High Accuracy and Sensitivity—P. P. Cioffi, "Bell Laboratories Record", June 1952.*

CAPACITANCE AND CONDUCTANCE BRIDGE

Ranging in resistance from 100 ohms to 100 megohms and with a range of capacitance of 1 picofarad to 1 microfarad, this bridge approximates "state-of-the-art" precision in the measurement of capacitance and conductance of electrolytes. (Other special capacitance and conductance bridges have been constructed with ranges for other applications.)

COMPONENT EQUIPMENT

The instrument consists of a special capacitance and conductance bridge mounted on a mobile desk-type console with a self-contained oscillator and null detector. The bridge is fully shielded by the metal top plate. Rear connections are provided for the oscillator, detector and unknown.

APPLICATIONS

	Resistance	Capacitance
RANGE	100 ohms to 100 megohms effective a-c resistance	1 pF to 1 μF
ACCURACY	±0.02% up to 1 megohm reducing to ±0.04% above 1 megohm*	±(0.5% + 0.5 pF) up to 2000 pF; ±0.1% above 2000 pF
RESOLUTION	0.001% or 0.001 ohm, whichever is larger, at values of 300 ohms and above	Infinite, readable to 0.1 pF

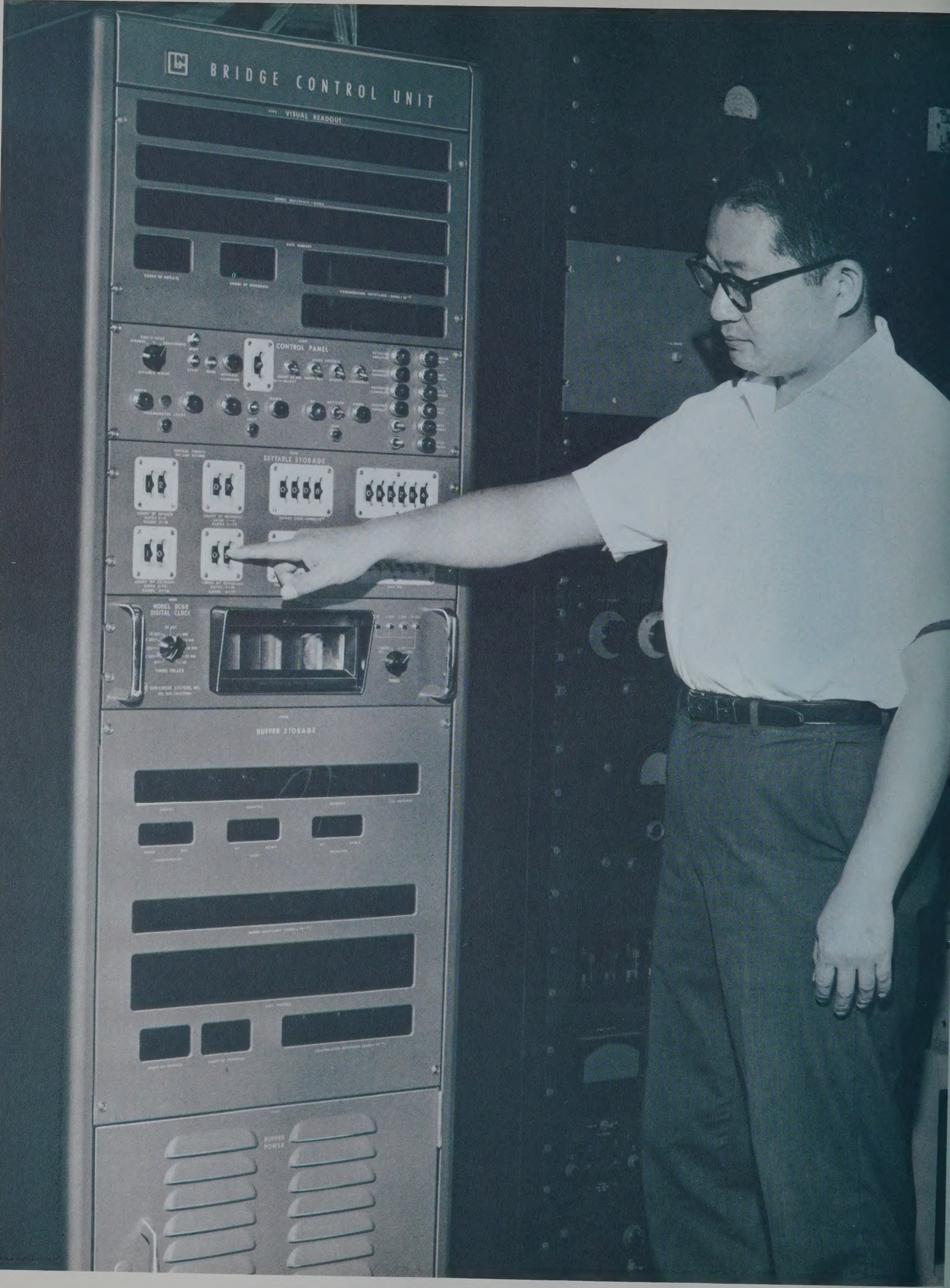
**Calibration corrections provide 0.01% up to 1 megohm, 0.02% up to 100 megohms.*

AUTOMATIC PER-CENT LIMIT BRIDGES

Leeds & Northrup has manufactured many versions of an automatic per-cent limit bridge for a variety of test applications. These limit bridges indicate acceptance or rejection of resistors under test by comparing them to a standard resistor, within established limits of tolerance. Basically, all of the per-cent limit bridges utilize a Wheatstone arrangement with equal ratio arms, segmented to allow selection of identical upper and lower limits. "Accept" or "reject" signals are obtained by using two detectors with opposing input polarities, each connected to different points in the bridge and each driving relays. The relay contacts are connected so an accept signal will occur only if both detectors are energized.

The range of resistance measurement has gone as high as five megohms using discrete steps in the standard arm, and as high as 100K-ohm steps using a decade arrangement in the standard arm.

Input and output configurations have varied with each bridge. Inputs have ranged from a single unknown resistor to a sequential arrangement for checking ten resistors at a time. Output indication has usually utilized incandescent lights and/or relay contacts. On a few bridges, counters were also supplied to indicate the total number of resistors tested and the number rejected. Switch settings, such as nominal resistance and per-cent tolerance, are made manually but these can be programmed remotely. Limit bridges have also been built for production testing of potentiometers. The tests include total resistance and residual resistance at each end when the slide is driven to that end.


BRIDGE CONTROL UNIT
VISUAL READOUT
CONTROL PANEL
SETTABLE STORAGE
MODEL DC58 DIGITAL CLOCK
BUFFER STORAGE
BUFFER POWER

J

LABORATORY CONSOLES

0 2 4 6 8 10 12 14 16 18 20
SPEEDOMAX W
D-C NULL DETECTOR
LEEDS & NORTHRUP
7555 TYPE K-5 POTENTIOMETER

LABORATORY CONSOLES & MOUNTING ACCESSORIES

With the introduction of a new line of all-metal consoles, L&N can provide a complete assembly of laboratory instruments for your sensing, indicating and recording requirements. This includes responsibility for assembly, wiring, and checkout of the complete system. These attractive consoles permit a more efficient use of space available in the modern instrumentation laboratory, and provide a greatly improved appearance compared with the usual odd-sized boxes and exposed interwiring.

"HIGH-BOY" CONSOLE

The "high-boy" consoles are especially dimensioned for optimum flexibility to mount the desired combination of instruments and accessories, and all related components. Mounting within the console minimizes the possibility of physical damage to instruments and protects interconnections from mechanical disturbances and drafts. Interconnections to lower-mounted accessories are direct. Equipment is angled for optimum convenience of the operator. There is no need for an auxiliary stand to position a null detector at the proper height.

These consoles provide an integral desk top, storage cabinet and top shelf. Casters are provided for ease of mobility. Brakes on the front casters and turn-down legs provide stability when permanently located. Consoles can be interlocked side-by-side for a neat measuring-station arrangement.

Three basic high-boy console styles are available:

(1) All instruments slope-mounted on one plane, 15 degrees from the vertical.
(2) Combination of 15-degree slope (15¾″) and vertically-mounted instruments (8¾″).
(3) Combination of 15-degree slope (12¼″) and vertically-mounted instruments (12¼″).

The basic high-boy console is also available separately for mounting your existing instrumentation.

DIMENSIONS—56½″ (h) x 23″ (w) x 26″ (d); 23″ (w) x 15″ (d) writing surface.

LIST NUMBER AND PRICE—A complete explanation of the built-up List Number and pricing for various high-boy consoles appears on the following two pages.

CONSOLE ONLY (Does not include instruments, hood or filler plates)

LIST NUMBER—4000

PRICE—$600.00.

"LOW-BOY" CONSOLE

A "low-boy" console is available for the bench-top mounting of facilities or individual instruments. The low-boy also provides casters, front-caster brakes, turn-down legs and cabinet storage, and can be interlocked with high-boy consoles. A set of angle brackets can be ordered which permits the positioning of instruments at a convenient operating angle on the low-boy desk top.

LIST NUMBER—4000-L

DIMENSIONS—30″ (h) x 23″ (w) x 41″; writing surface projects 15″.

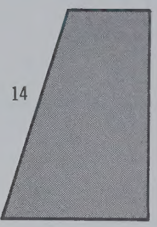
PRICE—$400.00.

127272 ANGLE BRACKETS (PAIR)

This pair of nylon-covered metal brackets is ideal for mounting laboratory instruments on a table or bench top. Instruments are positioned at a slope of 60 degrees from the horizontal. The brackets can be used with Type K-4, K-5 and K-6 Potentiometers, the 4737 Wheatstone Bridge, and such instruments as the 4261, 4306, 4385, 4760, 7582, 7592, 7645 and 8063.

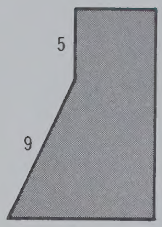
PRICE—$13.50 pair.

THREE BASIC HIGH-BOY CONSOLE STYLES:



1- ALL INSTRUMENTS SLOPE-MOUNTED ON ONE PLANE 15 DEGREES FROM VERTICAL

Mounts any combination of instruments (Table 1)
and filler plates (Table 3) whose suffix numbers add to exactly 14.

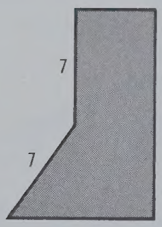


2- COMBINATION OF 15-DEGREE SLOPE AND VERTICALLY-MOUNTED INSTRUMENTS

(Suffix 5 HOOD)

Mounts on sloped plane any combination of instruments (Table 1)
and filler plates (Table 3) whose suffix numbers add to exactly 9.

Also mounts on vertical plane any combination of instruments (Table 1)
and filler plates (Table 3) whose suffix numbers add to exactly 5.



3- COMBINATION OF 15-DEGREE SLOPE AND VERTICALLY-MOUNTED INSTRUMENTS

(Suffix 7 HOOD)

Same as 2 above except the total of the suffix numbers add to 7 and 7.

BUILT-UP LIST NUMBER

Base Number	Suffixes 1st	2nd	3rd	4th	5th	6th	7th
4000	**-A3** ☐	**-B** ☐	**-C** ☐	**-D** ☐	**-E** ☐	**-F** ☐	**-S**

SUFFIX		
1st	**-A3** ☐	Insert the panel height (suffix number) of the instrument which is to be mounted nearest to the bottom of the panel space. Select from Table 1.
2nd	**-B** ☐	Insert the panel height (suffix number) of the second instrument from bottom. Select from Table 1. *Note that the 4385-1, 7592-1 and 9912-1 mount next to each other side by side. Accordingly, insert only one suffix number for any combination of these instruments within one mounting frame.*
3rd	**-C** ☐	Insert the panel height (suffix number) of the third instrument. Select from Table 1.
4th	**-D** ☐	Insert the height (suffix number) of the vertical hood, if desired. Select from Table 2.
5th	**-E** ☐	Insert the height (suffix number) of the filler plate, if required, to complete the mounting in the sloped panel space. Select from Table 3.
6th	**-F** ☐	Insert the height (suffix number) of the filler plate, if required, to complete the mounting in the hooded vertical panel space. Select from Table 3. *FILLER PLATES: In general, it is recommended that required filler plates for the sloped mounting be below the instruments and for the vertical hood be above the instruments.*
7th	**-S**	Denotes the optional features and/or accessories to be mounted within the console. Select from Table 4 and list the selection by word description.

IMPORTANT: A word description must follow the built-up list number and must list the arrangement from bottom to top in which the instruments and filler plates are to be mounted. Include in this description a list of the special features and/or accessories to be mounted within the console.

TABLE 1: INSTRUMENTS

Instrument	Description	Suffix
4232-3B	6-Dial High Precision Wheatstone Bridge	6
4287-1	Kelvin Bridge	4
4289-1	Wheatstone Bridge	4
4385-1	Shunt Box	3
4395-1	Precision Voltage Divider	5
4398-1	6-Dial Double Ratio Set	7
4399-1	7-Dial Precision Potential Divider	6
4399-C	Lead Compensator	2
4737-1	6-Dial Guarded Wheatstone Bridge	6
7554-1	K-4 Universal Guarded Potentiometer	6
7555-1	K-5 Universal Guarded Potentiometer	6
7556-1	6-Dial Guarded Precision Potentiometer	6
7565-1	Standard Cell Comparator	7
7592-1	Volt Box	3
8064-1	Resistance Thermometer Bridge	4
8064-A1	Resistance Thermometer Bridge	4
8686-1	Millivolt Potentiometer	4
8687-1	Volt Potentiometer	4
8690-1	Millivolt Potentiometer	4
8691-1	Millivolt Potentiometer (Double Range)	4
8692-□□□-1	Temperature Potentiometer	4
8693-□□□-□□□-1	Temperature Potentiometer (Double Range)	4
9834-1	Guarded D-C Null Detector	5
9876-1	D-C Power Supply	5
9912-1	Run-up Box	3
Speedomax H or W (short door)		7
Series 60 Control Unit or M-Line Model C Modules		4

TABLE 2: VERTICAL HOOD

Size	Suffix
8¾″	5
12¼″	7

TABLE 3: FILLER PLATE

Size	Suffix
1¾″	1
3½″	2
5¼″	3
7″	4
8¾″	5
10½″	6
12¼″	7

TABLE 4: ACCESSORIES

7308	Unsaturated Standard Cell
7311	Saturated Standard Cell Assembly
7597	Two-Volt Storage Cell
9878	Guarded D-C Constant Voltage Supply
9879	D-C Constant Voltage Supply

Standard Cell switch for use with 7311 and 7308 combination

Detector switch for use with 9834-1 and combination of instruments

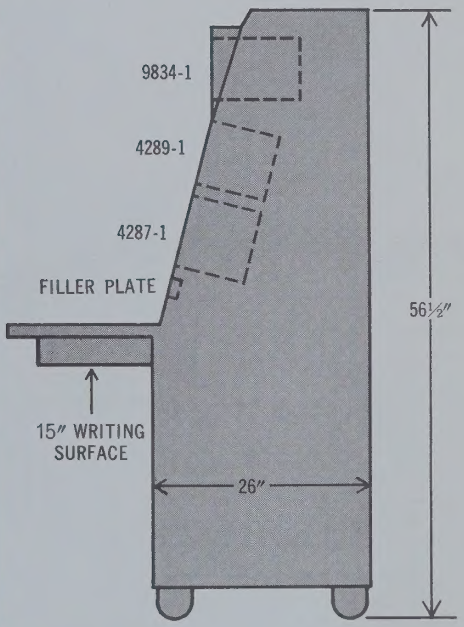
EMF switch for 16-point selection of input to Type K-4, K-5, and K-6 Potentiometers

EXAMPLE OF LIST NUMBER

4000—A34—B4—C5—D5—E1—S

Order of mounting in sloped space	Units	Total
Filler Plate	1	
4287-1	4	
4289-1	4	
	9	9
Order of mounting in vertical hood		
9834-1	5	5
		14

Special Feature: Switch next to 9834-1 to connect 9834-1 to either the 4287-1 or the 4289-1



PRICE

Console, Base Price	$900.00*
Vertical Hood	100.00
Switches (for each of three types in Table 4)	60.00**
Filler Plate, Suffixes 1 to 3 ... each	15.00
Suffixes 4 to 7 ... each	25.00
Engraving (available on filler plates only)	$15.00 plus $0.50 per character.
Instruments and Accessories	Listed selling price of each.

**Includes assembly, interconnecting, and testing of all components on a single console.*

***Includes identification on mounting plate and/or switch dial. Terminal board included where necessary.*

LEEDS & NORTHRUP
WHEATS
D-C POWER SUPPLY
LEEDS & NORTHRUP
GUARDED WHEATSTONE BRIDGE

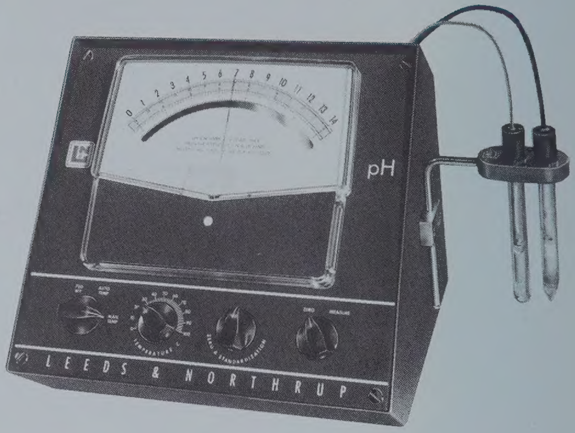
K

MISCELLANEOUS INSTRUMENTS

pH Meters K-2
Electrochemograph K-4
Macbeth Illuminometer K-5
Optical Pyrometers K-6

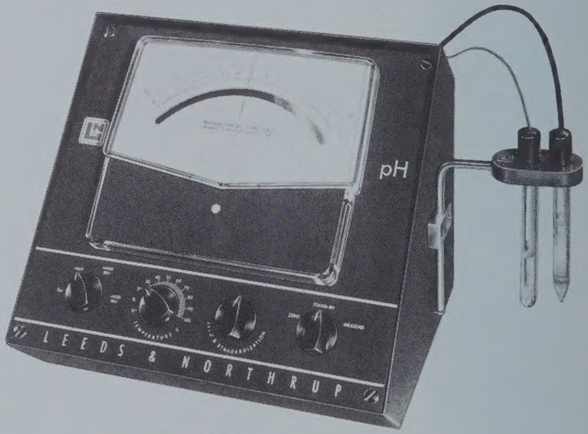
7400-A2 SERIES pH METERS

A selection of three models of line-operated L&N pH meters permits a choice of the meter best suited to your range, readability, accuracy and price requirements. The basic amplifier circuit, a design pioneered by L&N and widely imitated, is feed-back stabilized. On all models, conversion to a-c is accomplished with a dual-element, photo-conductive modulator. Containing no moving parts, this L&N-designed "solid-state" device avoids self-generated stray signals associated with mechanical converters. Circuitry is hand-wired. Basic with L&N, these design qualities insure the highest possible signal fidelity and the least possible unwanted noise. Because of their time-proven, progressive, electronic circuitry, L&N pH meters can be relied on for long life, trouble-free service, fast response, and unfaltering accuracy.



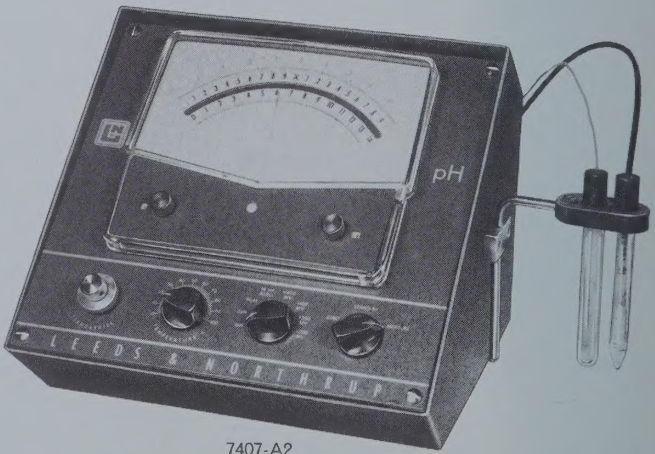
7401-A2

7401-A2 pH METER—Designed for general-purpose service, this model is especially well-adapted to routine measurements of high accuracy in plant or laboratory. Providing ranges of 0 to 14 pH, 0 to ±700 mV, and 0 to ±1400 mV, this responsive meter is reproducible to 0.02 pH with a relative accuracy of ±0.05 pH.



7405-A2

7405-A2 pH METER—With expanded scale, this model meets the more exacting requirements of pharmaceutical, clinical and chemical research or quality-control applications. Providing ranges of 0 to 14 pH, any 2-pH span, and 0 to ±1400 mV, this fast-response meter is reproducible to 0.003 pH with a relative accuracy of ±0.01 pH.



7407-A2

7407-A2 pH METER—The unmatched response and high sensitivity of this meter make it ideal for pH measurement of blood samples and other body or biological fluids. It permits the direct reading of any 1-pH or 2-pH span selected, with reproducibility and readability of 0.002 pH and a relative accuracy of ±0.005 pH. Ranges of 0 to 14 pH and 0 to 1400 mV and any 200-mV span are also provided.

SPECIFICATIONS

Specifications are common to all models unless otherwise stated.

METER—Taut-band, mirrored scale for parallax correction. Scale length is 7″.

SOURCE RESISTANCE—0 to 2000 megohms (up to 5000 megohms under favorable conditions).

INPUT CURRENT—1 x 10^{-12} amperes, maximum.

TEMPERATURE COMPENSATION

7401-A2—Manual, 0 to 100 C, or automatic with Thermohm® compensator (ordered separately).

7405-A2—Manual only, 0 to 100 C for 0 to 14 pH (full range) and 6 to 8 pH (expanded).

7407-A2—Manual, 0 to 100 C for 0 to 14 pH (full range) and those expanded spans between approximate limits of 6 and 8 pH. (On other expanded spans, buffering at sample temperature is recommended.) Automatic compensation on 0 to 14 pH range only, with Thermohm compensator (ordered separately).

RECORDER OUTPUT—From terminals on rear of instrument: d-c current, −500 to 0 to +500 μA. Convertible to d-c millivolts by adding resistor externally. (No circuit modifications required.)

KARL FISCHER MEASUREMENTS—10 μA polarizing current provided for dead-stop end-point measurements.

For lower currents, terminals for auxiliary resistor are provided. (No circuit modifications required.)

CONNECTIONS—All terminals are at rear of case.

GROUNDING—Operates on grounded or ungrounded electrode systems without special solution-ground connection. Seven-foot line cord with American Standard C73.1 plug, 3-pin, 3-wire grounding type, with adapter to two-pin with grounding pigtail.

POWER REQUIREMENTS—120 volts, 50 to 60 Hz, 45 watts. 240 volts, 50 to 60 Hz, available at extra cost; specify 7402-A2, 7406-A2, or 7408-A2, instead of 7401-A2, 7405-A2, and 7407-A2, respectively.

CASE — Steel, vinyl-coated for chemical protection. Front panel is aluminum with scratch-resistant melamine finish. Case dimensions, 11″ (w) x 8½″ (d) x 9″ (h); weight approximately 13 lb.

ACCESSORIES & SUPPLIES

Furnished with each meter, kit 124640 contains the following accessories and supplies:

1—145045 electrode holder assembly
1—117169 measuring electrode
1—117208 reference electrode
1—Std 1262-1 potassium chloride
1—Std 1199-AR measuring electrode guard
1—103-1-0-2 16 oz reference buffer solution, 6.86 pH ±0.01 pH at 25 C, in polyethylene bottle
1—095052 dust cover
1—095177 anti-static dust cloth.

PRICE—7401-A2, $330.00; 7405-A2, $470.00; 7407-A2, $545.00. (Subject to consumer quantity discount.)

OPTIONAL ACCESSORIES

STD 1199-47-1 AUTOMATIC TEMPERATURE COMPENSATOR THERMOHM® RESISTANCE THERMOMETER Provides compensation for changes in solution temperature over the range of 0 to 100 C. (Requires 145207 Clip—separately ordered—for attachment to 145044 or 145045 Electrode Holder.) Price—$48.00.

145027 COMPENSATOR CLIP; Price—$7.20.

011720 10-OHM RESISTOR—Recorder drop coil converts milliampere output-signal span to a millivolt span of −5 to 0 to +5 mV; $3.90.

011707 20-OHM RESISTOR—Converts output-signal span to a millivolt span of −10 to 0 to +10 mV; $3.90.

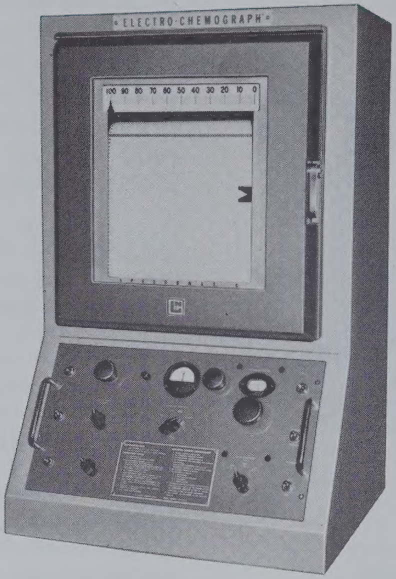
011640 50-OHM RESISTOR—Converts output-signal span to a millivolt span of −25 to 0 to +25 mV; P.O.R.

COMPARISON OF PERFORMANCE CHARACTERISTICS

Meter	7401-A2			7405-A2			7407-A2				
Range	Full-Range Only			Full-Range		Expanded	Full-Range		Expanded		
	pH	mV		pH	mV	pH	pH	mV	pH		mV
Readout	0 to 14	0 to ±1400	0 to ±700	0 to 14	0 to ±1400	Any 2-pH span	0 to 14	0 to ±1400	Any 1-pH Span	Any 2-pH Span	Any 200-mV Span
Smallest Scale Division	0.1	10	10	0.1	10	0.01	0.1	10	0.01	0.01	1.0
Reproducibility	0.02	2	1	0.02	2	0.003	0.02	2	0.002	0.002	0.3
Relative Accuracy	±0.05	±10	±5	±0.05	±10	±0.01	±0.05*	±10	±0.005*	±0.005*	±1.0
Amplifier Drift (non-cumulative)	Negligible	Negligible		Negligible	Negligible	<0.003	Negligible	Negligible	<0.003	<0.003	<0.3

*At buffer point.

62200 ELECTRO-CHEMOGRAPH®



The Electro-Chemograph, an instrument which measures and records polarographic information, is a valuable tool for making qualitative and quantitative analyses in research and test laboratories. It consists of a Speedomax G recorder, a polarizing unit and a power unit, all conveniently mounted in a neat, console-type cabinet with a sloping control panel. Integrated design makes possible a wide variety of chemical analyses with ease and precision, free from the effects of vibration and electrical disturbance. The electronic balancing system of the Speedomax microampere recorder eliminates the need for a vibration-free location. A stable, high-gain amplifier permits detection of current flow with only negligible effect on polarization voltage indications. The recorder provides a continuous-line record and is equipped with a chart tear-off device, fluorescent illumination and solenoid-operated pen lifter.

SPECIFICATIONS

Comprises a Speedomax G recorder, a high-speed polarizer, shielded leads for connections to electrode assembly and all controls and accessories (except dropping-mercury electrode assembly and power unit).

SPEEDOMAX G RECORDER

CURRENT RANGES—1, 2, 3, 5, 7, 10, 15, 20, 30, 50, and 100 μA.

BALANCING TIME—1 second full-scale, nominal, for zero damping effect.

CHART SPEED—2 inches per minute.

CURRENT STANDARDIZER—Manual.

POWER SUPPLY — Operates on 120 volts, 60 or 50 hertz as specified.

POLARIZER

POLARIZING POTENTIALS — Synchronous-motor-driven slidewire potentials of 0 to −2, −1 to −3, and +1 to −1 volts.

RATE OF APPLICATION—200 mV per minute.

CONTROL PANEL

CURRENT RANGE—Eleven-point selector switch.

RECORDER ZERO—Continuously adjustable dial.

DAMPING—Four-point selector switch.

CHART SWITCH—Three-point selector switch for (1) starting the chart, (2) stopping the chart, and (3) lifting the pen, with chart in motion.

POLARIZING RANGE—Three-point selector switch.

OPERATION SELECTOR—Four-point selector switch for (1 & 2) determining polarity of polarizing voltage, (3) disconnecting slidewire and cell for zero positioning, and (4) connecting current-calibration circuit.

STANDARDIZING ADJUSTMENT—Continuously adjustable knob.

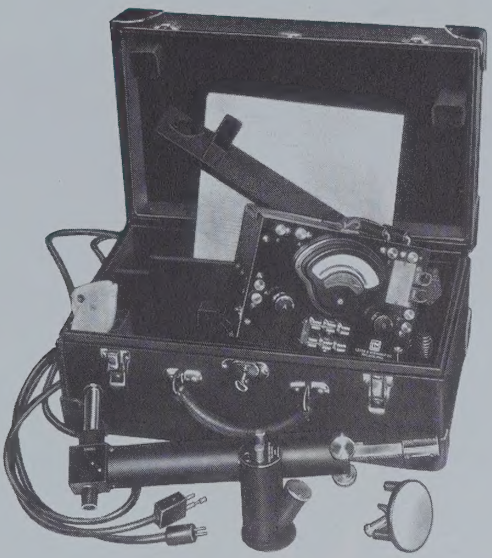
CASE—Table-top console-type unit, 18½" x 22" x 34½"; weight approx. 170 lbs.

PRICE—$2,750.00.

RECOMMENDED ACCESSORIES

101-2-0-1 Regulated Power Supply
7736 Polarotron® P-40 Dropping-Mercury Electrode Assembly

6800 MACBETH ILLUMINOMETER



Field measurements of exterior and interior lighting systems are made with laboratory accuracy through the use of a portable, easy-to-use photometer—the Macbeth Illuminometer. Measurements can be made in schoolrooms, workshops, offices, streets, highways . . . for studying natural as well as artificial illumination. Special screens are available for use in solving special colored-light problems such as measurements of light from fluorescent, mercury-vapor, and sodium-vapor lamps.

Direct reading in foot-candles for rapid measurements of illumination on a surface, its nominal range of 1 to 25 foot-candles is extended by two neutral absorbing screens to cover a range from approximately 0.01 to 2500 foot-candles. The range can be further extended by additional screens, supplied when specified.

The instrument is used to measure illumination on surfaces (foot-candles), and to determine brightness of illuminated surfaces of illuminating sources (candles per square foot) and luminous intensity of sources (candles). It operates on the null-balance principle, comparing the measured quantity with a certified standard.

The illuminometer consists of a Lummer-Brodhun cube, mounted in a rectangular head at one end of a tube which encloses the working-standard lamp. Turning a knob on the illuminometer moves the lamp back and forth in the tube, so it can be adjusted to balance the light admitted from the source under observation. Current in the lamp is set and held at a predetermined value indicated on a milliammeter supplied as part of the equipment. A reference-standard lamp to be used in checking the working standard is also supplied.

SPECIFICATIONS

6800 MACBETH ILLUMINOMETER

A compact, portable photometer for measuring illumination. Range, 1 to 25 foot-candles, extended by means of two absorbing screens to about 0.01 to 2500 foot-candles. Includes:

6810 ILLUMINOMETER TUBE—Comprises photometer head with Lummer-Brodhun cube for comparison by equality of brightness, on a tube enclosing a comparison lamp. Lamp is mounted on one end of a position-adjusting rod which has a scale 1 to 25 foot-candles. Supplied with L&N Report of Calibration.

6812 CONTROLLER—Comprises battery, rheostats, milliammeter and other parts for control of illuminometer lamp, in a case with a carrying strap.

6814 REFERENCE STANDARD—With L&N Report of Calibration. Comprises metal housing enclosing a calibrated lamp for standardizing the illuminometer.

6818-10 ABSORPTION SCREEN—Factor within range of 8.3 to 12.7, with L&N Report of Calibration.

6818-100 ABSORPTION SCREEN—Factor within range of 83 to 167, with L&N Report of Calibration.

6820 TEST PLATE—With L&N Report of Calibration.

M-10023 WORKING-STANDARD LAMP—Two extra.

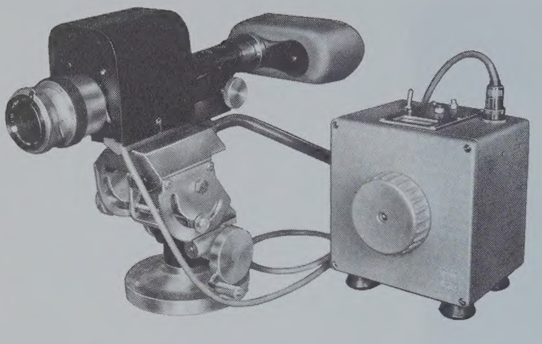
6832 CARRYING CASE—Leather, 10″ x 17″ x 6¾″.

6801 MACBETH ILLUMINOMETER

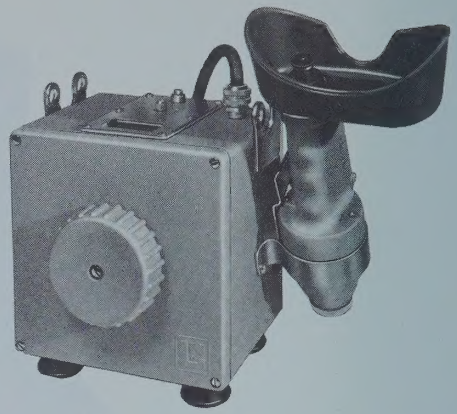
Same as the 6800, but in place of the 6810, includes a 6811 Illuminometer Tube with additional ratio scale for use with a sphere photometer.

PRICE—6800: $2140.00; 6801: $2273.50.

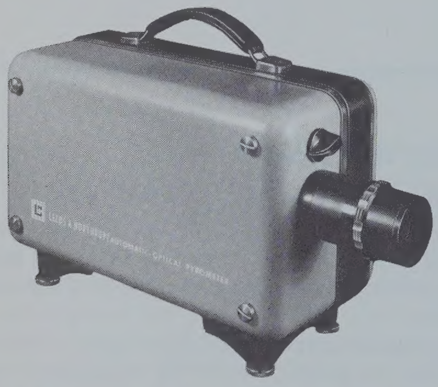
OPTICAL PYROMETERS



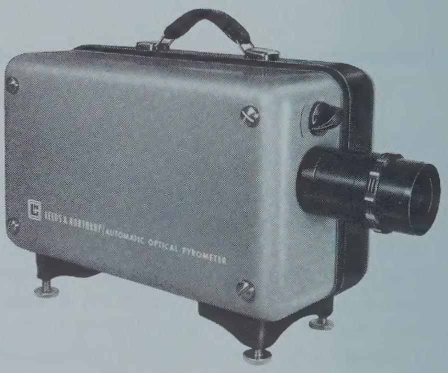
8634 PRECISION OPTICAL PYROMETER—A precision, high-sensitivity potentiometer-type pyrometer for measuring brightness temperatures by the "disappearing filament" method.



8636-C SINGLE-ADJUSTMENT OPTICAL PYROMETER—Potentiometer-type instrument for visual temperature measurement of incandescent objects by the "disappearing filament" method.



8641 MARK I PRECISION AUTOMATIC OPTICAL PYROMETER—A portable laboratory instrument for measuring brightness temperatures of objects or substances. Resolution: 0.5 C.



8642 MARK II HIGH-PRECISION AUTOMATIC OPTICAL PYROMETER—A high-sensitivity, high-precision laboratory instrument for automatically measuring temperatures over a wide range. Resolution: 0.15 C.

List Number	Temperature Ranges	Target Size	Target Distance	Price	For More Information, Request Data Sheet
8634	775-1225 C 1075-1750 C 1500-2800 C 1950-6200 C	0.006″ or larger	5.4″ or greater	$950.00	B1.4123
8636-C	1075-1750 C 1500-2800 C 2500-4200 C	1/32″ or larger	7″ or greater	700.00	B1.4121
8641	775-1225 C 1075-1750 C 1500-2800 C	0.096″ or larger	20″ to ∞	3750.00	A1.4111
8642	775-1225 C 1075-1750 C 1500-2800 C 2000-5800 C	0.048″ or larger	20″ to ∞ and 12″ to 20″	Approx. 6000.00	—

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L&N TECHNICAL LITERATURE

Fundamentals of D-C Electrical Measurements	Sup. Inf. A0.0001
Suggestions for Equipping a Standards Laboratory	Tech Pub. A0.0111
Celsius-Fahrenheit Conversion Table	Tech Pub. A1.0001
Calibration Techniques for Precision Platinum Resistance Thermometers—D. Robertson & K. A. Walch	Tech Pub. A1.2101
Recent Trends in Resistance Thermometry—H. L. Daneman & G. C. Mergner	Tech Pub. A1.2102
A Self-balancing Bridge with Range and Precision Adequate for a Platinum Thermometer—A. J. Williams, Jr. & G. C. Mergner	Reprint A1.2211RP
General Principles of Thermoelectric Thermometry—D. I. Finch	Tech Pub. D1.1000
Calibrating and Checking Thermocouples in Plants and Laboratories	Folder A1.1121
Optical Pyrometry—P. H. Dike, W. T. Gray & F. K. Schroyer	A1.4000
Notes on the Kelvin Bridge	Notebook E-53(1)
A Voltage Divider Standard—L. C. Fryer	Reprint AIEE 62-43
Moving Coil Galvanometers—D. H. Gallagher & A. E. Paschkis	Tech Pub. A12.1110
Fault Location in Cables	Tech Pub. B5.1130

FEDERAL STOCK NUMBERS

L&N LIST NUMBER	FEDERAL STOCK NUMBER	L&N LIST NUMBER	FEDERAL STOCK NUMBER	L&N LIST NUMBER	FEDERAL STOCK NUMBER
1540	6625-794-4420	4222-B	6625-649-2649	7592	6625-679-3264
2100	6625-490-2555	4223-B	6625-629-1998	7593	5905-885-4230
2284-b	6625-669-1952	4232-A-1	6625-033-8621	7597	6625-713-2103
2284-c	6625-668-5678	4232-B	6625-783-5342	8064	6625-908-0880
2284-d	6625-564-9482	4249	6625-858-1154	8064-A	6625-867-6629
2285-a	6625-649-0054	4258	6625-618-9193	8067	6625-490-1719
2340-a	6625-957-2453	4300	6625-679-7881	8069-B	6685-490-1720
2430-c	6625-585-3859	4320	6625-673-5929	8072	6625-444-6111
2430-d	6625-585-1647	4360	6625-648-8498	8163	6685-526-8241
2435-c	6625-510-1814	4361	6625-679-7882	8401	6640-629-1993
2665	6625-737-9568	4363	6625-679-7886	8410	6685-L0096252006
3294	5930-490-1875	4385	6625-657-3635	8686	6685-822-6913
3701	5930-646-7605	4395	6625-679-3262	8690	6625-987-3834
3702	6625-679-7885	4755	6625-303-0576	8692-048*	6685-857-0604
4020-B	6625-649-2647	4775	6625-224-6289	8692-009**	6685-856-8680
4025-B	6625-649-2780	4776	6625-249-6569	8693-062-167***	6685-847-1793
4030-B	5905-490-3075	5300	6625-649-2726	8700-24	6695-799-7307
4035-B	6625-649-2781	5305	6625-490-1724	9834	4931-778-4763
4040-B	5905-097-0425	5430-AM-1	6625-243-4846	9835-B	6625-547-5286
4045-B	6625-730-8602	6800	6695-490-2475	31-3-0-3	5930-593-4418
4210	6625-884-3552	7308	6625-490-1875	31-3-0-4	5930-898-7713
4221-B	6625-649-2779	7582	6625-329-2940		

**Range, 0 to 300 F for iron-constantan thermocouples.*

***Range, −100 to +500 F for iron-constantan thermocouples.*

****Ranges, 0 to 600 C and 500 to 1200 C for Chromel-Alumel thermocouples.*

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